METAL

DECEMBER 1935

PROGRESS

(Left)
Discharge end of furnace showing conveyor on automatic quench tank.

(Below)
Charge end of furnace, showing Controlled Atmosphere Preparation Unit at right.

SC Controlled Atmosphere Furnace Gives Clean, Uniform, High Quality Production

Springs that day after day meet the exacting requirements of the manufacturer, are hardened in the above furnace. Satisfactory results are achieved because of correct engineering—the correct application of heat—the correct atmosphere—and accurate control.

Consult our engineers regarding your heat treating problems. They will be glad to tell you about this and many other applications of SC Controlled Atmosphere Furnaces.

Controlled Atmosphere Furnaces

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TOLEDO, OHIO — Sales and Engineering Service in Principal Cities

Also makers of.. ATMOSPHERE FURNACES . . . HARDENING, DRAWING, NORMALIZING
ANNEALING FURNACES . . . FOR CONTINUOUS OR BATCH OPERATION

METAL PROGRESS

Vol. 28 *December, 1935* *No. 6*

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Owned and Published by

American Society for Metals

Issued monthly, subscription $5 a year. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, Ohio, under the Act of March 3, 1870 . . . American Society for Metals is not responsible for statements or opinions printed in this publication. Editorials are written by the editor and represent his views. He is also sponsor for unsigned and staff articles . . . . Ernest E. Thum, Editor, 7016 Euclid Ave., Cleveland, Ohio

Trained Metallurgists Needed

THE OTHER DAY the Editor was at a large steel plant, talking with the chief metallurgist. He was hired prior to the War and there were five men ahead of him. Now he has 75 men observing steel making operations in the plant and contacting customers — 75 men on these two classifications alone!

That fact might be a text for an essay on the change in personnel required to convert a "tonnage mill" to quality, but it actually led to the question, "Where did you get these men?" They were hired from time to time from likely applicants, largely as chance directed. Few were definitely trained as metallurgists by an engineering college.

Such a situation is reflected everywhere. Metallurgists are being made by practice rather than being trained by colleges — except insofar as a metallurgist is a converted mechanical or chemical engineer. Proof is the growth of the American Society for Metals — comprised as it is of men who have to know something about metals to hold their jobs or to grow into a better position. They have joined by the thousand to get this "post-graduate" information.

Evidence also accumulates that the college faculties are not yet alive to this condition. Refer to the data collected by Prof. W. B. Plank of Lafayette College, for *Mining and Metallurgy.* Although the number of students enrolled for various courses in mineral technology (principally mining, metallurgy, petroleum, ceramics, geology, fuel) is at an all-time high, totaling 5564 in the United States and Canada in the academic year 1934-35, only 1027 of them were studying metallurgy. Only 189 were graduated last spring.

More men than that joined the American Society for Metals last month!

The situation is even worse than it looks by statistics, since too many of the metallurgical courses are given as options in mining schools, and emphasize the chemical aspects of metallurgy (smelting and refining) sometimes to the almost total exclusion of the physical operations in the user's and fabricator's plants — a field where most of the new jobs will be found. However, some hopeful signs of change may be noted.

What is really needed is ballyhoo. Metallurgy has never been dramatized. We never had a Goethals on the front page as builder of a Panama Canal; there have been no metallurgical Edisons; war babies in metallurgy there were in plenty, but they didn't get the publicity of the powder plants and poison gas. For that reason too many young men enter college with their imaginations kindled by the achievements of past days in other branches of engineering and without knowing the prospects of future success in the field of metals. These are the men who are later recruited for the jobs of controlling quality in metal, and they have to dig in and learn a lot of elementary facts they should have been taught in school.

The gist of the above paragraph has been said so many times it is almost bromidic. Unfortunately it is something we can't do much about. On the other hand there is an indication of a movement further back, in the manual training high schools. Some of these new ones — three or four built by Government funds in New York and Brooklyn are happy examples — have metallurgical equipment and teaching personnel which would be the envy of most of the established technical colleges. Youngsters who have been exposed to such influences and surroundings should soon be knocking at the doors of the institutions of higher learning, asking for more information about metals. A wise college president will prepare for their coming.

Discovery of the Double Quench for Carburized Parts

Now that the single quench for carburized transmission gears has been definitely established as good practice for certain steels, lately developed, it may be interesting to put on record the circumstances surrounding what I think was the discovery of the double quench for case hardened parts — at least as far as its application to automotive gears was concerned — an operation which held undisputed sway in quality parts for 25 years:

One Sunday, in Detroit in the early part of the summer of 1907, I read in the paper that a company was installing an experimental machine shop and plant layout department, prior to establishing an automobile factory in Saginaw, Mich. That company was the Ranier Motor Car Co., and James G. Heaslet (formerly of the Garford Mfg. Co. of Elyria, Ohio, and at the present time vice-president of Cleveland Tractor Co.) was to be in charge.

The next day I called there and was informed that Mr. Heaslet was the only man with whom to discuss steel. A day or so later I was fortunate to contact Mr. Heaslet. He politely informed me that he did not consider the Crucible Steel Co. of America, with which I was then connected, fitted to make automobile gear steel. He based his judgment on the fact that he had never known it to supply any quantity of gear steel to any of the leading automobile companies.

At that time this was the true situation, but after several visits I finally interested him and he directed me to call on C. L. Bockus, superintendent of Western Malleable Steel Co., which operated both a drop forge shop and malleable steel casting plant. He said he would tell him to give me the necessary sizes so I could supply a few samples of steel, as Mr. Bockus' company was going to make the drop forgings. The requirements of the gears were that they must be file-hard and the teeth tough enough to bend practically together when one tooth was placed on an anvil with a set hammer on the second tooth above and sledged.

I informed Mr. Heaslet I did not believe there was a steel that could be simply oil quenched (one of his specifications) and still be file-hard and as tough as he expected, without first being carburized. He told me that such an opinion showed either lack of experience on my part or of the company I represented, for salesmen for two other companies had told him that they could supply him with chrome-nickel steel that would be file-hard when simply oil quenched and still tough enough to permit the teeth bending together before breaking.

With these instructions in mind I secured an order for the samples and put the matter up to the mill. Naturally the reply was that our steel would be as good, if not better, than the other steels, and a chrome-nickel-tungsten steel made at the Atha works, Harrison, N. J., was sent to the Western Malleable plant.

After these gears were forged and machined Mr. Heaslet invited the representatives of the three competing steel companies to oversee the hardening. We all arrived there the same day and did our stunts. I still maintained, when Mr. Heaslet questioned me previous to the hardening operation, that none of the gears would be file-hard. He questioned each one of us separately, unbeknownst to the other two. Luckily for me, the other boys assured him they could meet his requirements, but all three tests were

By W. P. Woodside
Vice-President, Climax Molybdenum Co., Detroit

utter failures as far as hardness was concerned!

As we were about to leave the plant, talking to ourselves, a representative of the New Process Gear Co. of Syracuse, N. Y., came along and Mr. Heaslet told him what he was up against and the New Process representative said, "Why Jim, the only steel you should use is 3½% nickel carburized." Mr. Heaslet asked him where he could get it and again luck was with me for he said, "Sanderson Bros. Works." (This was another subsidiary of the Crucible Steel Co.)

We then had quite a little conference and the upshot was that Mr. Heaslet ordered Mr. Bockus to purchase the steel for the first few hundred gear sets. Some cars were then being built for the New York auto show, and a few demonstrators were needed for immediate delivery to the Ranier dealers.

Shortly after this the equipment and personnel in the Warren Avenue experimental shop were moved to the new Saginaw plant of the Ranier Co. and the forgings were shipped there and machined. Mr. Heaslet sent for me and I assisted him in setting up a furnace and getting the necessary carburizing boxes; he himself wired up the pyrometer as there was no one else in his organization capable of doing so — in fact, there were very few men in the city of Detroit able to do it.

We carburized the gears in bone long enough to get the desired case and proceeded to harden. Then the fun started! The gears were brittle — or rather I should say that the teeth broke out when sledged in the manner mentioned above. Naturally Mr. Heaslet said that I didn't know my business and got in touch with the New Process Gear Co. and was told to quench at 1450° F. That didn't do any good! We then wired the mill and it recommended 1500° F. The gears were tougher but still didn't meet with Mr. Heaslet's approval, so he talked with his friends representing the other two steel companies and they recommended practically the same heat treatment that the Crucible metallurgists and the New Process Gear Co. had given Heaslet, and that was "single quench."

Meanwhile it was getting toward automobile show time and Mr. Heaslet could see that he was going to be stuck for transmissions. In fact, it had then got to the point where a couple of models were waiting in an express car on the siding all ready to rush them to New York in time. Naturally, he was very much upset. I had been there nearly a week working long hours setting up the furnaces, so I, too, was getting quite discouraged.

About five o'clock one night — I believe it was a Friday — Mr. Heaslet came out to the hardening room with the superintendent, James Davidson, and when he saw that there had been no improvement he went right up in the air and told me a few things about my company, about myself and all the rest! (He tells me he had been on his feet 72 hr., and that probably explained his condition.)

Naturally that wasn't easy to listen to. I had two gears in the furnace at that time and I took one out, quenched it and broke it. When I found no better results I threw the gear down in disgust, washed my hands, put on my coat and started out of the plant. During the interval the furnace had crept up to about 1550° F., for Mr. Cornell, who had charge of the blacksmith shop in which the carburizing and heat treating furnaces were set up, wanted to use this small furnace to harden some tools. When he found the other gear in there he asked me what he should do with it, and I told him to throw it in the oil for it wasn't any good anyway; 1550° F. was surely too hot.

On my way out the watchman closed the gate and told me that I couldn't get out. Then I certainly did blow up and started looking for Heaslet with blood in my eye.

I found him resting on the veranda of the office building and when he saw that I was mad he started to smile. "So it's now your turn to go up in the air," he said. "Now let's not both of us lose our heads over this thing for we have simply got to lick this job. For God's sake don't leave me now for these cars have got to be in New York and I have to have at least one of them to use as a demonstrator. Let's go out and get something to eat."

So we went over to a place where we could get some dinner and after that I went back to work. I put two more gears in the furnace and while they were heating I decided to break the one that the blacksmith had thrown in the oil and I thought had been overheated. I found a very fine fracture — although I knew it was not tough enough to suit Mr. Heaslet; also the case was a little coarse. But anyway, here was something that was better than we had been getting, and my first thought on seeing this fine fracture was that the lower temperatures we had used on the others had not refined the core, and the 1550° heat treatment had. This thought was running through my mind: "That mill might have sent by accident some tool steel along with the nickel steel." Therefore, I decided to harden what was left of this gear at as low a temperature as it

Photographs Courtesy Cleveland Tractor Co.

would harden. Being a sliding gear, it had a thin flange, and I figured that if the steel was a high carbon tool steel this flange would harden if water quenched from 1425° F., for we had protected this flange very carefully with fire clay during carburizing.

To my surprise the flange did not harden the least bit, so I decided to break out another tooth and much to my surprise and great delight the tooth did not break! I tried all the teeth very severely with the file and found them all file-hard. Slowly it dawned upon me that we had stumbled on the right method to treat these gears! It was all very puzzling for we had tried these low quenching temperatures before in our efforts to try everything. I wondered if the preliminary high heat had something to do with the different results, so I ran another gear at 1550° F., quenched it, broke out a couple of teeth and found the fracture was very fine. I reheated this gear to 1425° F. and got another tough one. I heated another one to 1550° F., quenched it and went through the same routine, except that I dropped the quenching temperature to 1400° F. To my great delight I found it file-hard and exceedingly tough.

So I ran over to Mr. Heaslet's office and found him sitting there talking to Kirk Moore (now one of the "old timers" in the auto accessory business). He tried the gear with a file and after looking at the bent teeth asked if I could duplicate it. I believed that I could and he said, "Let's do it!"

We hurried out to the plant and double quenched another gear. It also came out satisfactorily and Mr. Heaslet moved that we all go home. We were then staying at the St. Vincent Hotel in Saginaw and we went down there but didn't go to bed. (Remember this was in the pre-Volstead days!)

To the best of my knowledge this was the first double treated gear used in an automobile. I made out my report and sent it to our Pittsburgh and Syracuse offices and received word from them that the treatment was all right and generally used. The letter was signed by the late E. L. French (or at least the signature looked like his). Dr. French visited Detroit a few months afterward and in the meantime I had talked the old E. M. F. Co. into treating pinion gears by the double quench. When Dr. French witnessed this operation and was told that it was done to get tough gears, he replied, "Nonsense; 1500° F. is the proper temperature to use. I never heard of this double treatment."

I asked the doctor if he was sure he had never heard of it, and upon returning to the office showed him the letter he had written. He looked at it a minute and said, "That is a duplicate of my signature. My clerk probably came into my office when I was busy and told me what you had said in your letter. As the report indicated that everything was going fine, I probably told him to write you saying that the report was O.K., and he wrote it up the way he thought best."

The double treatment had evidently never been used before, for if it had the telegrams and telephone calls that Mr. Heaslet made would not have all been answered with recommendations for the single treatment. Another indication of this fact is as follows:

Walter Phipps, who was superintendent of Cadillac's gear and engine division, was a man who had made quite a study of the heat treating of gears, and when I demonstrated what could be done by double treating steering knuckle pins made from carburized ordinary carbon steel, as well as double treating 3.50% nickel steel gears, he said that he had never heard of the process and wondered if I couldn't get a patent on it. I told him that I didn't think so, because I understood the "fiberizing" of armor plate really involved what we were doing to these alloy steel gears and other carburized parts.

A metal envelope for a vacuum tube required three essential developments—first, rapid welding of vacuum-tight joints; second, a gas-tight insulation; and third, a method of sealing a very high vacuum

Metal Replaces Glass in Radio Tubes

METAL VACUUM TUBES are being widely advertised as an innovation in radio receivers, and to metallurgists they are interesting as an instance where metal is replacing glass. (One metal is substituted for another metal so often that it ceases to be news, but when metal replaces glass or fabric it is a different and news-worthy story!) Consequently the Editor reports some information given him during a recent visit to Schenectady by W. C. White of the vacuum tube engineering department, under whose guidance the development occurred.

In reality the idea of a metal casing for a vacuum tube is not new, but its early application was prevented by the lack of proper metals or processes of manufacture. Consequently, a device using glass bulbs with wires of expensive alloys leading in the electrical circuits was the first practical solution.

This was reasonably satisfactory (if the fragility of a glass container could be discounted) until tubes of higher and higher power were being built. For this reason: Current is carried in a high vacuum by a flow of electrons — negatively charged particles — from a heated cathode (usually an "activated" wire or ribbon) to the anode or receiving plate. These electrons move at high velocity, and their incessant bombardment on the anode heats this metal plate and this heat must be carried away else the anode will melt, even though it is made of molybdenum or tungsten. It is obvious that in a power tube it is very difficult to radiate this heat from inside a glass bulb. The same problem exists in X-ray tubes, and was discussed briefly in an article on gas-free metals by Messrs. Coolidge and Charlton in METAL PROGRESS for November, 1933.

A correct solution of this problem occurred independently to research workers in both the General Electric and Bell Telephone laboratories. It was to make the anode end of the tube, where the electrons strike, of a copper cylinder and cool this metal by a water jacket. From this idea grew the semi-metal tubes, some of them as much as five or six feet high, now used for radio sending stations. This involved a metal-to-glass seal, and it is ingeniously made by tapering the open edge of the copper cylinder to a feather edge and lapping it over the glass, the feather edge having such small structural strength that it could plastically deform with the changing volume of the glass, as it heated and cooled, without breaking the seal. This construction was first described by W. G. Housekeeper in 1923.

The second step toward the "all-metal" radio tube had to be taken several years ago when large electron tubes were being applied to other devices than radio equipment. ("All-metal" should be enclosed in mental quotation marks, for there are always the non-metallic insulators necessary.) For instance, rectifiers for changing alternating to direct current, and frequency changers for alternating current, must handle currents of large amperage and the necessary glass structures were large and very costly. Cost was high because the tubes were not made in quantity and because the envelopes had to be produced by highly skilled glass blowers. Faced with expensive and fragile structures the question naturally arose: "Why cannot we make

these casings of metal, which is certainly vacuum tight, and can easily be worked on highly developed machinery with labor of ordinary skill?"

Before this question could be answered affirmatively, three problems had to be solved, and fortunately they were solved almost simultaneously. Problem A was to make an absolutely tight joint between various metal parts — for instance, base, body and top of the outer casing. Problem B was to devise an insulating seal for the lead-in wires, and one that would not crack and leak under wide variations in temperature. Problem C was to learn how to clear the metal container of its dissolved, occluded and adsorbed gases and then seal the vacuum.

Problem A was solved by refinements in the resistance welding process. Parts to be joined were lapped, pressed together between conforming electrodes, and a high current flashed through for a fraction of a second, so short a time, in fact, that even though the abutting surfaces merged in a welding heat, the outer surfaces remained cool to the touch. (Such electrical control, by the way, is effected by gas-filled, three-electrode tubes knowns as thyratrons.) The engraving shows how a flat base for a small sized power tube is punched and ribbed preparatory to welding in two eyelets. It also shows a radio tube base with seven eyelets, which had all these joints simultaneously made by hydrogen brazing (a process described in Metal Progress, February, 1935, wherein a bit of copper is placed at each joint and the assembly passed through a furnace with deoxidizing atmosphere, heated above the melting point of copper and cooled before removal).

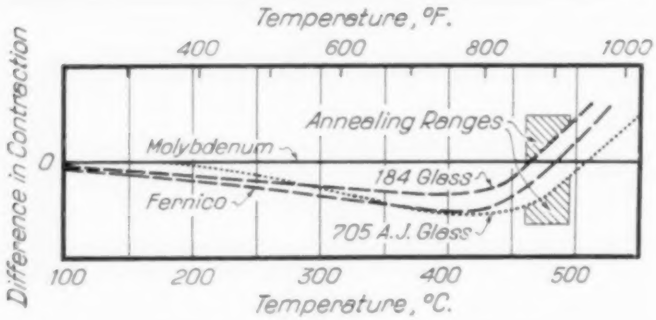
Alternative Construction of Vacuum Tube Bases. Flanged eyelets of "fernico" are welded into the larger base plate, whereas all seven joints in the smaller one are made simultaneously and automatically by hydrogen brazing

An economical insulating seal for the lead-in wires was a large problem. A variety of conductors can be led through a glass wall without short circuits, since the glass itself has high electrical resistance, but obviously each wire must be carefully insulated from a metal sheath. This insulation must be vacuum tight, and remain so despite considerable changes in temperature during operation, to say nothing of manufacture, assembly and exhaust. If an easily made glass-to-metal seal could be devised, a bead or cylinder of glass would serve excellently for insulation.

This problem had already been encountered in the incandescent lamp industry. A lead-in wire through glass must be of metal of fair electrical conductivity so the passing current will not heat it unduly; it should be easily workable to small wires; it should be "wetted" by hot glass so as to form an effective seal; it should have a similar coefficient of expansion to that of the glass so this fragile seal might not be broken as temperature varies; it should be inexpensive. Platinum was first used; however, the lamp industry fairly quickly devised a number of substitutes. For many years the standard has been "dumet," a composite wire invented in 1913 by B. E. Eldred. It has a 42% nickel steel core with pure copper sheath, the latter comprising about one-quarter the volume. This material was also adopted by the radio industry for lead-in wires in glass tubes.

Its principal disadvantages are its cost and, for larger tubes, its low conductivity and its longitudinal expansion differing by 40% from its expansion in a radial direction. Neither figure matches glass very well, and the material functions principally because of the ductility of the copper sheath, and is therefore limited to wires less than 0.040 in. diameter for currents up to 20 amp. Lead-ins in larger tubes and lamps, made of hard glass, are of tungsten or more recently of molybdenum wire. 26 to 28% chromium-iron has been used extensively in Europe, but is a poor match for glass if the seals are to be annealed.

Development of a ductile alloy of iron, nickel and cobalt fortunately occurred just at the time its need was pressing. A. W. Hull and E. E.



Difference in Contraction Between Two Hard Glasses and Two Metals. Molybdenum is taken as standard, for it was best previously known; fernico parallels hard glass very closely. (After Hull and Burger)

Burger of the General Electric Research Laboratories have described the studies leading up to it in an interesting article on "Glass-to-Metal Seals" in *Physics*, December, 1934. The new alloy is "fernico" consisting of 54% Fe, 28% Ni, and 18% Co. As shown by the graph, its coefficient of thermal expansion is almost identical with that of high resistance glass or hard glass up to the softening point. The remarkable change in expansivity at about 800° F., paralleling that of glass, is associated with the fact that the Curie point of the alloy is at about the same temperature as the transition in glass, and the coefficient of thermal expansion of the alloy in its magnetic state is luckily only one-third as much as in its non-magnetic state.

Fernico is economically made in ordinary steel mill operations, and can be drawn into fine wires and stamped into deep cups. The character of its scale is such that the oxides are readily soluble in glass, and a vacuum-tight seal is formed when the metal is heated enough to soften the glass in contact with it. Although its electrical conductivity is low as compared with pure copper, it is ample for small currents in small tubes, and heavier conductors can be butt welded to either side of a plate of it so that in circuits carrying heavy currents the amount of fernico is inconsequential. (Similar parallelism with the expansion of softer lead glass and lime glass is had by another alloy, called "fernichrome" by Hull and Burger, and containing 37% Fe, 30% Ni, 25% Co and 8% Cr.)

Two pieces of fernico are used for a lead-in through a metal casing. For small tubes an eyelet is welded or brazed into the steel casing and a short wire with a bead of glass midlength is centered in the opening so made. For heavier circuits a "pillar" type of lead-in is used, consisting of a cup welded to an opening in the sheath and a cylinder of insulating glass supporting a fernico cap. Axially through or to this cap may be welded a stiff conductor for high currents.

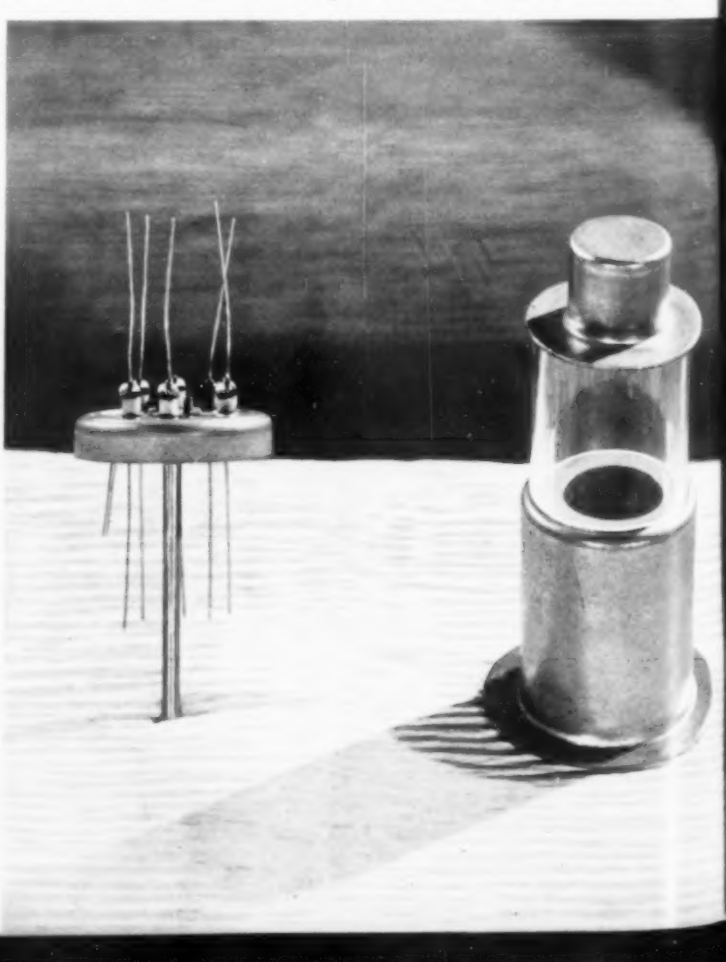
Standardization of Tubes

These details have been standardized into a relatively few sizes for a wide range of utility. Thus ten types of radio receiving tubes have but three sizes of shells, and these all have the same diameters so that one set of welding electrodes will serve all. Position and function of leads and base pins are also standardized (No. 1 pin is always the ground for the shell; No. 3 pin is always the plate lead, and so on) which is a boon to the set manufacturer and radio service man.

The last problem mentioned above — of getting and sealing the vacuum — is not greatly different from the glass or semi-metal tube. As shown by the photograph below, a small exhaust pipe is welded into the base and when the series of de-gassing and evacuating operations is complete, this is merely pinched flat between welding electrodes, a tight weld made by resistance, and the surplus length cut off.

It should be remembered that the above de-

Lead-Ins for Small and Large Circuits. Each requires two pieces of expansion alloy. In radio tubes the fernico wire and eyelet are separated by a glass bead; in power tubes the glass cylinder is the insulator, and an axial conductor (not shown here) is butt welded into the top and bottom of the fernico cup

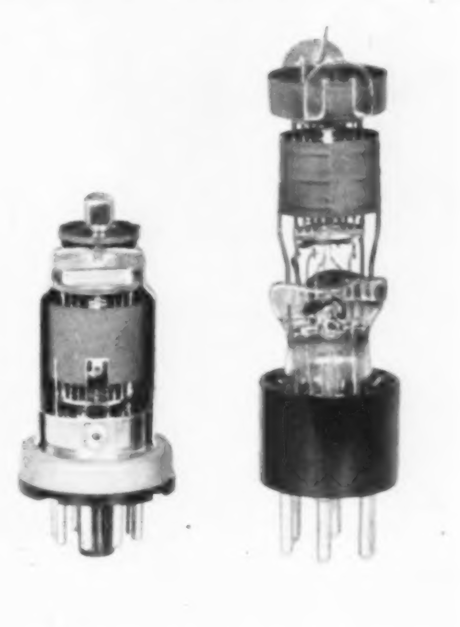


velopments were made to improve the large electron tubes used in power circuits. How its application to small tubes for radio receivers came about within recent months will now be reviewed.

Electron tubes for receiving and amplifying wireless signals could be classed as laboratory productions during the ten years prior to the War, but like innumerable other things were dislocated during the 1914-1918 period. French army officers sensed the importance of using vacuum tubes for short range radio transmission as soon as warfare settled down to siege operations in trenches, and a quick demand for quantity production of small vacuum tubes arose. The electrical industry turned to the incandescent lamp plants for help, and this is responsible for many of the features of the conventional radio tube, such as the glass stem sealing in all the connections, the glass bulb and the base cemented on. All these features were the product of semi-automatic machinery already highly developed.

However, this was not the most desirable ultimate solution of the problem, for an incandescent lamp is designed to let energy out, whereas in radio amplification the opposite is essential — namely to reduce the escape of electrical energy to zero. This is responsible for the fact that for many radio applications auxiliary walls must be erected inside and outside the envelope of a glass electron tube. Certain receiving tubes, for example, have a cylindrical plate anode which is bombarded by electrons on its inner surface. It is surrounded by the glass sheath necessary to maintain the vacuum. Next the inner surface of the glass is coated with graphite to make it a conductor and thus prevent differences in potential from stray bombardments. Lastly a closely fitting "can" is placed around the entire tube as an electrostatic shield, to guard against external influence. All three of these (inner shield, bulb and outer shield) it so happens can be replaced by a single envelope of low carbon steel, a cheap, easily worked metal, vacuum tight and a good conductor of electricity and heat.

When this is done, following the methods described above for power tubes, one most striking advantage is the reduction in over-all size without any reduction in size or clearances of the essential internal structure. This is due to two facts — one, that the metal parts can be manufactured with great precision; tolerances are correspondingly reduced to a few thousandths of an inch greater than that necessary for design clearances. Second, the basing of a metal tube can be made more rugged and compact; a glass stem must have a rather long skirt so that when its outer end is fused to the bulb the seals at the top will not crack or otherwise be harmed by the heat. The result is that lead-in wires at least one inch longer are required, correspondingly increasing the over-all length of the tube. Flat steel tops instead of domed glass tops further reduce the length.



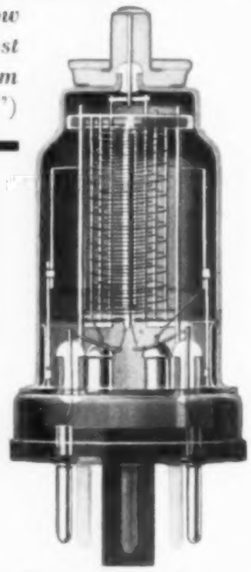
Two Radio Receiving Tubes of Similar Function. Metal envelope on left-hand tube is half cut away showing that anode, grid and cathode are unchanged in size and spacing. Height of glass construction shown at right is mostly due to size of the seal and base

These smaller outside dimensions (averaging one-half the volume) can, of course, exert a marked influence on the size of the receiver chassis, particularly in mobile and portable sets. Short leads and much better external shielding result in improved characteristics which help both to eliminate "tube noises" and to permit greater amplification, especially on short wave reception (now an important function of all radio receivers). Here it should be emphasized that metal tubes are not to be used merely as substitutes for glass ones — in fact, reception may not be improved at all unless the entire receiver is built to utilize their characteristics.

Manufacturing Advantages

A number of manufacturing advantages are following the metal bulb in addition to those noted above. Speed of making the unit opera-

Metal Envelope and Anode Are Cut Away to Show Inner Grids and Cathode. Tubulation for exhaust is sealed and then sheathed with insulation to form central locating plug on base. (Courtesy "Inco")



tions is one. Resistance welding of metal parts is almost instantaneous and can be done on dial feed mechanism at speeds limited only by the feeder.

Copper brazing of joints can also be done automatically in a production line of any desired capacity, whereas the heating of glass to the softening point must be done rather delicately — a glass-to-glass seal taking from one to two minutes. Attachment of the base is another matter; cement must be used with glass whereas the steel skirt can merely be peened or rolled over the molded base to hold it firmly in place. Even though the metal-working machinery is more expensive in first cost, it operates very rapidly, with high precision, and requires less skilled and more readily obtainable labor.

Metals Inside the Tube

Much might be said about the internal structure of the electron tube since the various parts, filaments, plates and grids must have definite thermal, electrical and metallurgical characteristics, often in a very difficult combination. The essential parts are shown in the drawing above, where the envelope and cylindrical anode (plate) are cut away on their diameter to show the grids and axial cathode within.

No great change has been made in the essential design and materials (other than the bulb) and it may be said briefly that the parts are as follows, in order from axis outward:

The heater is a coil or loop of tungsten wire, insulated from the cathode by alumina. The cathode is a small cylinder of nickel sheet, a refractory, non-corrosive metal, coated outside with a layer of barium and strontium oxides. After preliminary heating in vacuum (an operation called "activation") enough of the barium oxide is reduced to metal so that the barium becomes an efficient and self-renewing source of electrons necessary to carry the current.

Next surrounding the cathode there may be up to three and even more grids; in the one illustrated there are the "control grid," the "screen grid" and the "suppressor grid" in order from inside out. They are alike in construction, being very fine molybdenum wire wound in a loose helix of proper size, each turn being spaced by notching into two stiff nickel wire supports, placed diametrically opposite. Molybdenum is chosen because it is rigid and nondistorting at operating temperatures and emits very few disturbing electrons; the nickel support is inexpensive, soft, ductile, and has high thermal conductivity.

The anode is of nickel for the same reasons; it should be kept as cool as possible, even under bombardment, to prevent stray electrons from being thrown off, so the smooth surface is frequently covered with carbon black to increase its thermal radiation.

Evacuation of these completed tubes to low pressures is done on a table, rotating to various stations, very much as is done in the incandescent lamp industry. An important difference is that all the metal in the tube (and it is a relatively large amount) must be "de-gassed," so that it will not exude any harmful gas after sealing and during operation. This is most simply done prior to assembly by a hydrogen anneal, which also reduces oxides on the surface. Molybdenum is especially well cleaned of surface oxides in this way. Nickel may be effectively de-gassed in 15 min. at 2200° F.; the surface is effectively decarburized in an hour in hydrogen at the same temperature.

Preparation of High Vacuum

Water vapor is difficult to remove from the vacuum tube and is a most harmful residue. Consequently after the tube has been pumped out on early stations on the evacuating table, it is heated both by external heat and internal electric currents, to "boil out" any adsorbed water vapor. Evacuation still continues and the cathode is activated by a measured large current. When the vacuum pump has done all it can in a given short time and the pressure has been reduced to something less than a millionth of an atmosphere, the small exhaust tube is pinched flat and welded tightly shut.

There still remain, however, enough gas molecules to interfere with good operation and these are fixed in solid form by reaction with a

"getter," such as a magnesium-barium alloy enclosed in the tube for that purpose. In the ordinary glass tube this getter was held in a metal cup and the latter heated to the reacting temperature by high frequency induction. This method of heating is unnecessary with a metal sheath, so the getter is attached to the shell itself and flashed by heating that spot externally with a tiny gas torch. The vaporized metal deposits on the cooler inner surface of the metal shell, having first combined with all of the harmful gases and vapors. This reduces the gas pressure many fold and correspondingly reduces the number of wandering molecules which can be ionized and interfere with the orderly flow of the electron stream.

It will be observed that the metal envelope for radio tubes has not changed the internal structure or functions of the device; it is, however, a good example of how metallurgical development of an expansion alloy, and the application of most modern metal working and welding equipment have resulted in an important change in a device entering the American home at the rate of 50,000,000 a year.

Micrurgy

By B. L. Clarke and H. W. Hermance

Condensed from Industrial and Engineering Chemistry

THE WORD "micrurgy" was originally coined to describe biological micro-dissection. Since the term, by its derivation, means "operations on a small scale or work with minute quantities," it can logically be used to include micro-chemistry, micro-analysis, and chemical microscopy.

A laboratory designed to handle general problems in the examination of materials by micrurgical technique has been evolved at Bell Telephone Laboratories, and the article describes the equipment in considerable detail. Much of the equipment and many of the processes are unique and highly ingenious.

Tests on materials analyzed or examined are usually of a diagnostic nature; samples from service failure are submitted and the cause and cure is desired. Work includes the following classes of metallic materials: Electrical conductors, magnetic alloys, structural materials, and transformation products. Two examples will illustrate the types of problems in which micrurgical methods are effective:

Contact points of various metals and alloys are widely used in telephone apparatus, as in relays and switches. Rapid qualitative analyses are frequently required to identify the alloy. Usually only a single contact is available and this must not be destroyed. Sufficient sample is obtained by drawing the metal across a roughened spot on a microscope slide. The resulting streak is dissolved in acid, transferred to a clear glass slide, and evaporated. Identification of this residue is made by reactions carried out under the microscope.

The micrurgical laboratory is frequently called upon to diagnose cases of high contact resistance. In one case welded silver contacts developed high resistance. An extremely thin tarnish film was detected on the silver. Sulphide was demonstrated and the presence of copper was made strikingly evident by pressing the contact points on ammoniacal diethyl-dithio-carbamic acid test paper. The weight of the tarnish film on one of these contacts was not more than a few ten-thousandths of a milligram. The copper contamination probably came from the welding electrode.

The other example is the analytical examination of lead cable sheath. Micrurgical methods of analysis are of great service, particularly in diagnosing cases of failure. When the sheath is corroded it is necessary to distinguish between the different types of chemical and electrolytic corrosion, and, in seeking the cause, to examine the environment. Lead peroxide, chlorides (anodic products), and free alkali (cathodic), in abnormally high concentration, are indicative of electrolytic corrosion. Such substances are quickly and graphically detected by specific indicator papers.

A corrosion product on lead cable sheath, examined by test tube methods, might show no active ion, and the analyst would be at a loss to diagnose the corrosion cause. Under the microscope, however, tiny pockets might be found which contain a high chloride concentration, easily detected micrurgically because the test is made *in situ* and not after dilution below the sensitivity of the test.

Plant and laboratory research has developed many copper alloys which surmount the natural disabilities of the older brasses and bronzes and match the severe specialized demands of modern industry

Corrosion Resistance of Copper Alloys

Corrosion resistance of copper and its alloys has been known for more than 8000 years, and museums have many surviving examples of tools and implements from ancient Egypt, Spain and Peru. Aside from its electrical conductivity, which is responsible for about half the present consumption, the extensive modern use is due principally to its corrosion resistance.

The rate of attack by mineral and organic acids on commercial copper is dependent upon the presence of an oxidizing agent and other ions in solution. The metal copper is very resistant to alkaline and basic solutions. It also resists oxidation by water vapor at high temperatures but is susceptible to attack by many salt solutions. For many corrosive agents to which copper itself is not highly resistant, suitable alloys have been developed.

Corrosion of Copper Alloys

A. Selective Corrosion — Certain types of corrosion are frequently associated with copper alloys, although they are by no means peculiar to them. One is selective attack, by which one constituent is preferentially removed. So-called "dezincification" occurs in such of the copper-zinc series, or brasses, as contain less copper than about 80%; those containing more copper are immune to it. The present consensus is that the zinc and copper go into solution together, the copper being subsequently redeposited in a porous mass. Dezincification may proceed by the formation of a more or less uniform layer of copper on the inner wall of the pipe, or the attack may occur locally with the resultant formation of isolated plugs of copper.

It is a common cause of the failure of Muntz metal and yellow brass pipe. In such alpha-plus-beta brasses the beta phase is frequently attacked, leaving the alpha crystals in apparently sound condition. Brasses containing 70 to 80% (all alpha structure) are not immune, however.

Dezincification takes place in many aqueous solutions and may occur in those which are alkaline as well as those which are acid. It occurs more rapidly the higher the temperature; also the tendency is for local rather than uniform dezincification with increasing temperature.

Selective attack may also occur with special brasses or other copper alloys containing manganese, in which case the manganese is removed. An excellent example occurred in one of our laboratory investigations of two alloys, one containing 85% copper, 10% manganese and 5% tin, and the other 85% copper, 10% manganese and 5% cobalt. Analysis of the masses of redeposited copper showed in each case about 94% of copper, proving that manganese was selectively dissolved. Selective attack of aluminum has also been noticed in some of our test work with 8% aluminum bronze.

B. Oxygen Concentration Cells — The presence of oxygen or uneven aeration in the corroding solution is a very important factor in deter-

By N. W. Mitchell
Chase Brass & Copper Co.
Waterbury, Conn.

mining both the rate and the distribution of corrosion of copper alloys — in fact of all metals. Evans has shown that on a specimen partially immersed in a solution, the metal in contact with the liquid meniscus is cathodic and protected and that the metal below the water line is anodic and corrodes. In his experiments two similar pieces of metal were immersed in two compartments of a cell divided by a porous partition. Both compartments were filled with half normal potassium chloride solution and the two pieces connected to a milliammeter. When bubbles of air free from carbon dioxide were passed over one of the metal strips a current registered on the milliammeter, the aerated strip being the cathode and the un-aerated strip the anode. The latter dissolved during the experiment.

The important fact which this experiment establishes is that the presence of oxygen alters the potential of a metal, rendering it electropositive to a specimen of the same metal immersed in the same solution in the absence of oxygen. Thus a small current may be set up between two portions of the same metal to which oxygen is supplied at different rates. Another important point established is the direction of the current, which is provided by the consumption of metal from the un-aerated electrode — that is to say, the portions to which oxygen has least access are where corrosion is greatest.

This conclusion is at first sight paradoxical, but the action of oxygen is of the direct chemical type and produces a film having some protective qualities. These parts are ennobled, and the other portions of the metal which have less ready access to oxygen are relatively electronegative and dissolve by anodic attack of the ions in solution. This explains water line attack so frequently noted in practice. With solutions like copper sulphate, which creep considerably, the water line area becomes highly cathodic and concentrated corrosion takes place just below.

It has often been noted that pitting type of corrosion frequently is induced by lodgment of stones, shells, dead plants or animals (the so-called "deposit attack"). These portions of the metallic surface are shielded from oxygen, either mechanically or by the reducing action of decaying organisms, and are therefore anodic to adjacent oxygen-rich areas; hence they corrode.

Concentration cells may also be formed by differences in concentration of other constituents of the solution than oxygen. They may also be formed by stirring a portion of the solution, the remainder being quiet; copper in contact with the moving electrolyte becomes the anode. This type of concentration may contribute to corrosion at the inlet of condenser tubes. Another common form of corrosion in condenser tubes is known as impingement attack, and results in deep pitting confined usually to the first few inches at the inlet. Impingement of water by the collapse of "vacuum bubbles" or change in direction of flow removes the naturally forming surface film, permitting corrosion to proceed at the bare spots. Variation in velocity of the solution near the inlet end with the formation of eddy currents may also set up concentration cells in which the metal in contact with the more rapidly moving water becomes anodic.

C. Intercrystalline Attack occurs with many metals under certain conditions. It results in a weakening of the bond between crystals or grains of the metal by penetration of corrodent at the grain boundary, at least superficially. Even in severe intercrystalline attack the grains themselves are usually left in the original condition.

There are three distinctions which may be made. One variety of failure occurs because of internal stresses within the metal plus a specific superficial corrosion. This is known as season cracking and has been a common cause of failure of high brass alloys, although it may be prevented by removing the internal stresses by low temperature heat treatment.

Even with internal stresses properly relieved some alloys may still fail by intercrystalline cracking if they are corroded while under sufficient external stress. This we refer to as "stress-corrosion cracking." The corrosive action causing both season cracking and stress-corrosion cracking need be but very slight. If the metal is entirely unstressed, failure at the grain boundaries is relatively rare. It does occur, however, under certain conditions (which are usually severely corrosive) resulting in a penetration of the grain boundaries and subsequent break-down of the metal along these boundaries. A distinction may therefore be made between season cracking, stress-corrosion cracking and intercrystalline corrosion; however, corrosive conditions are necessary for all of them.

Resistance of Copper Alloys

Copper-Zinc Series — The brasses are well known industrially, and naturally have been intensively studied as to their corrosion resistance. The conclusion may be broadly stated that the red brass containing 85% copper has a maximum

resistance not only to sea water but also to many other solutions.

For plumbing work the alloy first used was the high brass Muntz metal, consisting of 60% copper with the balance zinc. Corrosion by dezincification of the beta phase led to the adoption of a "two-and-one" alloy of 67% copper having an all alpha structure — but in certain types of corrosive waters, and in most waters used continuously at high temperatures, it has been seriously dezincified.

Use of red brass containing 85% copper, balance zinc, has greatly improved the life of plumbing work. In addition to having a maximum of corrosion resistance for the copper-zinc series, red brass will not dezincify under any conditions. It is also practically immune to season cracking, has a maximum of fatigue resistance for the copper-zinc series, and is a logical choice where good physical properties are required in addition to corrosion resistance.

Admiralty metal, an alloy of 70% copper, 29% zinc, 1% tin which has been used for many years for condenser and heat exchanger tubing in the marine, power plant and oil industries, is classed with ordinary high brasses with respect to its susceptibility to dezincification. At the present time, red brass is gradually replacing it where admiralty metal has failed by dezincification. One direct comparison may be given where admiralty pipe, handling hot sea water in certain hotels at Atlantic City failed in about two years; red brass is in good condition after eight years.

Admiralty metal has long been used for condenser tubing in marine work and power plants. Cooling water velocity has been greatly increased during the last ten years, and such tubes have frequently failed by impingement attack. Resistance to this type of corrosion depends largely upon the protection offered by a surface film, and such a film is formed by the addition of about 2% of aluminum to a high brass alloy. One such alloy has the composition 76% copper, 2% aluminum and the balance zinc. This aluminum brass forms a natural protective film when immersed in sea water, very adherent, healing rapidly whenever it is broken, and tubes of it have given many times the life of ordinary brass or admiralty tubes.

Unfortunately, however, aluminum brass of this copper content is very susceptible to plug type dezincification and wherever conditions are such that dezincification can occur this alloy is rapidly penetrated. There recently has been developed an alloy consisting of 82% copper, 2% aluminum, 1% tin and balance zinc in which the susceptibility to dezincification has been entirely overcome with no sacrifice of resistance to impingement.

Copper-Tin Alloys (bronzes) have been known almost as long as copper itself. Their resistance to certain forms of corrosion, particularly acid attack, is responsible for many uses such as pump liners and casings handling acids and other corrosive solutions. Tin bronze is well known in the form of castings for plaques and tablets exposed to the atmosphere. Phosphor bronze has a large field of usefulness for high strength corrosion resistant rods, tubing and wire. The usefulness of tin bronzes has been limited by the difficulty involved in working; search is now being made for a ternary bronze with better mechanical and working properties.

Copper-Silicon Alloys — In order to satisfy a demand for a high strength, corrosion resistant alloy that would be suitable for structural and fabricating purposes the silicon bronze alloys have been developed. In particular an alloy with copper 96%, silicon 3%, zinc 1% has resulted from long and careful laboratory and plant investigations. This alloy combines most of the properties desirable in engineering alloys to an unusual extent; modifications may be furnished which, in suitable temper, will fill almost any specification.

In general, the high strength silicon-copper alloys are equal or somewhat superior to pure copper in corrosion resistance; for many solutions they are markedly superior. The composition given above has a much greater resistance to season cracking and stress-corrosion cracking than most high strength alloys.

As examples of its many uses may be listed sand castings, bolts and nuts, forgings, propeller shafts, structural shapes and tanks of all kinds. This alloy may also be readily welded by any of the common methods.

Copper-Nickel Series — Copper and nickel are soluble in each other in all proportions. With the increasing corrosion of ordinary brass and admiralty condenser tubes and the search for more corrosion resistant alloys to replace them, study was given these solid solution alloys. The ones now used commercially contain 20 to 30% nickel, a few per cent of zinc being added in some cases to facilitate casting and manufacture.

It was found that alloys containing less than 20% nickel are not much better than brass in actual service. The behavior in service, however, of 20% and 30% nickel tubes was so su-

perior to that of brass that these alloys are being used for condenser tubing in the larger steamships and ocean liners, and have frequently given many times the life of the tubes they have replaced.

These copper-nickel alloys (even those containing a little zinc) are not susceptible to selective attack of the dezincification type and are entirely immune to season cracking.

Resistance of the copper-nickel alloys to alkaline liquids, saline solutions, sea water, boiler feed waters, dilute mineral acids and organic acids in fruit juices is very marked. This has led to many industrial applications. Since the copper-nickels consist of a single phase, corrosion when it occurs is usually uniform in nature rather than the localized types of corrosion and pitting which are most apt to lead to premature failures. In general the resistance increases with the nickel content.

Copper-Aluminum Alloys (aluminum bronzes) have gained a considerable reputation. The commercial ones contain usually 5, 8 or 10% aluminum. They have very high strength and hardness, and are used for pump parts, rods, propeller shafts and other similar parts.

For several reasons the use of aluminum bronze has been very limited. It is difficult to obtain good castings of the alloy and its hardness and strength have proved a drawback to its manufacture. Although resistant to many corrosive solutions, aluminum bronze is susceptible to selective corrosion in other exposures. This results in deep pitting of the alloy and in some cases to penetration by the formation of copper-rich plugs.

Nickel-Aluminum Bronze is an alloy of copper, nickel and aluminum which combines the favorable properties of the copper-nickel alloys and the copper-aluminum alloys while avoiding the undesirable properties of the latter. It was developed after many years of research for an acid resisting metal, and has been used for many years in the form of castings for steel pickling equipment, handling dilute sulphuric acid. The more recent manufacture of the alloy in the form of pipe, tube, sheet and rod has greatly extended its field of usefulness.

Due to its aluminum content, nickel-aluminum bronze has good resistance to hydrogen sulphide and for this reason is destined to be of great help to the oil industry for heat exchangers in refineries handling crude oil on one side of the tubes and oil vapors containing hydrogen sulphide and hydrogen chloride on the other side. The maximum temperature in most of these heat exchanger units is 450 or 500° F., and the conditions are usually too severe for all but very few alloys. Nickel-aluminum bronze has already been installed in many such heat exchangers, and present indications are that it will be highly satisfactory as well as economical for this use.

New Industries Rely on Old Materials —This Photograph Was Taken Inside a Large Copper Duct in an Air Conditioning System. Courtesy "Applied Photography" and Eastman Kodak Co.

Cast iron can be hardened and strengthened most easily by adding nickel, chromium and molybdenum to a low silicon base. High alloys of this sort are martensitic and come hard from the mold. Low alloys may be further benefited by heat treatment.

Hardening Cast Iron With Alloy Additions

Up to a few years ago, "hardening of cast iron" was a topic avoided by foundrymen. Too many of them were concerned with the problem of making easily machinable irons to expend much effort on developing hard ones! Gradually the idea that an iron could be both hard and machinable spread abroad and that the limit of machinability was fixed by the character of the casting's structure rather than by its Brinell hardness number. The trend toward harder and harder irons ensued until today the objective frequently consists of making castings as hard as the application, structure, and shape will allow.

The reason for this trend is obvious. It is done to reduce wear.

A great deal of discussion can be aroused over whether hardness bears any relation to wear. The correct answer may best be achieved by taking a long-range perspective of the progress of a decade, which clearly shows that machine parts subjected to wear are being successfully produced to higher and higher hardness levels. In fact, this progress is not limited to the gray or machinable irons, because the white or "unmachinable" irons, heretofore considered to be easily superior in hardness to the gray irons, were being replaced by the latter, so that even the white irons have had to be improved in hardness and wear resisting properties.

By J. S. Vanick
Development & Research Dept., International Nickel Co., Inc.

Means for making small changes in hardness of a cast iron are well known to all foundrymen, but they usually sacrifice other properties or risk losing the casting itself. Casting against chills is the commonest means, but this produces a skin densening rather than substantial hardening. Usually what would otherwise be a very soft iron is employed to avoid forming excessively hard spots in the chilled skin, and as a result, the remainder of the casting is open grained and lacking in strength or rigidity. Correct chill casting requires special analysis iron and special foundry practice.

Shops making machine tool castings, for example, are rapidly eliminating the use of chills for hardening ways and slides and pouring instead a stronger, stiffer, harder, unchilled, alloyed iron. An excellent example is F. J. Dost's article in Metal Progress for August.

A moderate pick-up of 10 or 15 numbers on the Brinell scale may be obtained in an unalloyed iron by lowering either the carbon or silicon content or both, thus lowering the amount of graphite and increasing the amount of combined carbon. The limiting factor in this practice is the occurrence of chill spots, chill edges, or brittleness. Increasing the manganese, sulphur or phosphorus acts similarly and has the same limitations. The so-called pearlitic irons, some of them processed by pouring metal of a specific composition into preheated molds, were limited by the same factors. Superheated irons offered another means for obtaining a small improvement in hardness, but they were accompanied by an astounding need for control in melting and precision in pouring.

All of these methods require that the foundryman take a chance on the results — really an unnecessary risk if the more positive methods of hardening to be outlined below are employed.

First, note should be taken of the function of carbon in cast iron and steel. The most common method for making a harder *steel* casting consists of increasing its carbon content from the usual 0.25 to 0.35% up to approximately 0.60 or even 0.80%. As a matter of fact, well-made gray iron, if its composition is properly balanced, should possess a "dissolved" or combined carbon content of about this higher order, with none of the free carbon segregated into knots or clusters. A "correctly balanced" iron will be defined as one containing just enough combined carbon to yield a full pearlitic structure; an "overbalanced iron" is one with excessive graphitization; an "underbalanced iron" one with inadequate graphitization. Throughout the following discussion, a perfectly balanced composition and casting is implied in which the graphite flake is just right as to size and discontinuity, and the body or metallic portion is fully pearlitic. Its achievement in actual practice with a plain cast iron (not alloyed) is not so simple.

Most commercial gray irons are "overbalanced" because they contain an excess of silicon, with the result that they are excessively graphitic and hardness levels may fall as low as 120 to 160 Brinell. This can be corrected by reducing the silicon, thus relieving the tendency to graphitize and building up the combined carbon content in the pearlite so that the resulting hardness in the otherwise unalloyed cast iron approaches 170 to 190 Brinell. Lowering the total carbon content accomplishes a similar result but this is naturally less susceptible to control in cupola melting than adjusting the silicon.

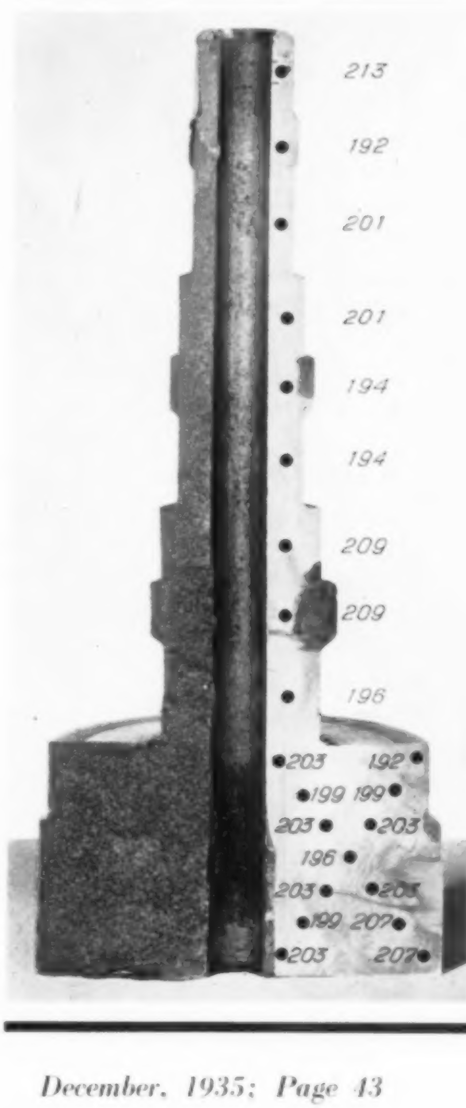
The nearer the base composition, as cast, approaches a hardness of 180 Brinell in the casting, the less slack will need to be taken up by the alloy additions in building the hardness of the casting up to the higher levels.

From these considerations it results that hardening by direct alloying is the most popular and economical means employed today. A good or even an indifferent grade of cast iron can be alloyed with suitable amounts of nickel and other elements such as chromium and molybdenum and the hardness increased from as low as 140 Brinell to 400 or 450. The quantity of these alloys needed to achieve maximum hardness may be as little as 0.75% for a very thin casting (1/8 in. thick) or as much as 6% for castings exceeding 2 to 4 in. thick.

Small Additions for Cylinder Blocks

The use of small additions of nickel and chromium or molybdenum (total under 2%) is usually confined to light sectioned or irregular shaped castings. The type which can be depended upon to respond well to a small addition of alloys is illustrated in the photograph below of an irregularly shaped casting, split down its axis, possessing a fairly uniform hardness and grain through wide changes in section.

Quite frequently, castings of this type require a preliminary adjustment in their microstructure to achieve uniform hardness. If the dominating structure is ferritic (as is characteristic of excessively high silicon types), then a small excess of chromium or molybdenum may be used to restore a full pearlitic matrix. On the other hand, if localized hard spots, corners or edges occur (representing segregated zones of



Uniform Hardness and Grain Size May Be Achieved in Castings of Irregular Section With a Moderate Addition of Nickel and Chromium (or Molybdenum) if the Original Composition Is Such as to Be Fully Pearlitic With Fine, Discontinuous Graphite Flakes. Tensile strength of this irregular casting is 35,000 psi.

ungraphitized carbides) then small additions of nickel alone will make the structure finely graphitic and fully pearlitic. From this base level achieved in either way, a gradual and steady response to increasing alloy additions can be expected up the hardness scale as illustrated in the chart alongside.

Nickel alone could be used to increase the hardness, especially in low silicon irons, except that 3 to 4% would be necessary to pick up 50 points on the Brinell scale, while nickel plus chromium will achieve the same results with less than half as much alloy and at considerably less cost. Since the alloying addition is balanced so that the carbide-forming tendencies of the chromium are checked by the nickel, the two elements combined raise the hardness level uniformly, without unbalancing the structure. A thin section requires less alloy to achieve a hardness equal to that of its neighboring heavier, more slowly cooled, thick section. It is also evident that the lower silicon compositions in these normal carbon compositions require less alloy; also that variations in hardness with mass for a given alloy content are less in the low silicon type than in the high silicon type.

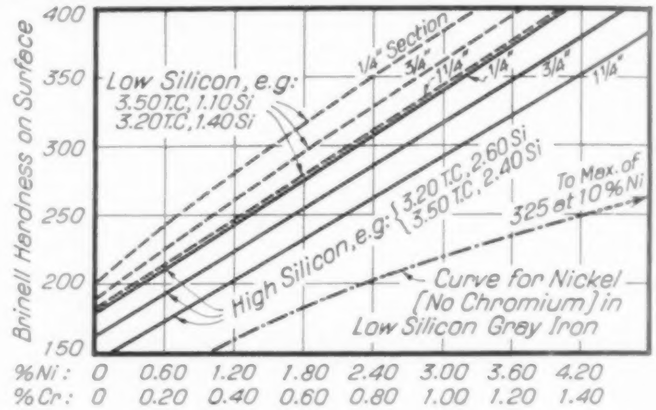
Excellent examples of hardening cast iron by small additions of alloys are illustrated in cylinder block castings — where not only is the prevailing hardness raised, but it is also equalized. Softened zones produced by the annealing effects of hot sand cores are erased, as shown in the diagram at top next page in the uniform hardness level of the cylinder bore in the region of the cored-out water jacket.

Machine tool beds, saddles, and heavy sectional parts illustrate another example of alloy hardened castings, where frequently only the heavy sections need to be machined and the lighter sections can be used with a somewhat out-of-balance alloy addition.

Other commercial castings employing this alloying procedure to obtain a desirable degree of hardness are cylinders for compressors, pumps and engines, castings like cams, clutches, brake drums and gears, and light sectioned machine parts. Occasionally, heavy sections such as machine tool beds and saddles are mildly hardened by the same amount of alloy which would distinctly harden thin castings.

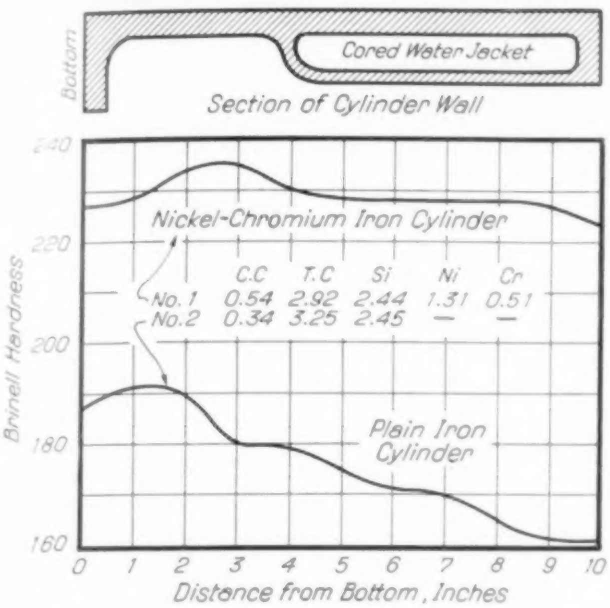
Moderate Additions for Heavy Castings

Nickel-chromium additions to a total of 2 to 4% are usually made to harden heavy sections moderately, as shown in the diagram at the bottom of the next page, or to harden greatly the light sections as shown in the diagram below. The lines shown on page 45 are general limits for rather heavy work; pieces 1x4x4 in. may be expected to be about 20 numbers harder than 4x4x4-in. blocks. Characteristic changes may also be observed in the microstructure. The rather coarse pearlite in the plain iron, hardness about 160, as viewed at 500 diameters magnification, becomes finer and finer with increasing nickel content, until at about 250 to 275 Brinell it is cloudy and unresolvable (a desirable structure ordinarily called sorbite). As hardness of 325 is reached and passed, martensite appears as a microconstituent.



Hardness Versus Alloy Content in "Balanced" Gray Irons. Lighter sections and lower silicon (that is, denser, pearlitic irons) require less alloy for a given hardness. Nickel plus chromium gives higher hardness than does nickel alone

The lower line on the diagram just above shows a gray cast iron will be hardened by increasing its nickel. The photographs on page 46 show that it also reduces the tendency to chill into hard, unmachinable iron. In the photograph the 2x4x4-in. chill blocks of car-wheel iron show the unalloyed block to consist mostly of chilled white iron, unmachinable and possessing a Brinell hardness of about 380. As successively larger nickel additions are made, the chill is decreased until at approximately 5% nickel no chill remains, even though the microstructure is martensitic with about the same hardness. The important distinction is that this chill-free or carbide-free structure is now machinable, whereas the base composition, chill cast, is not. (4 to 6% of nickel would obtain a Brinell hardness of only 275 in a good low silicon iron, while the data already given show that this hardness can be readily developed with about 3%



Cylinder Walls Hardened by Proper Alloying. Annealing effect of water jacket core on the plain iron is absent in the nickel-chromium cylinder

nickel plus 1% chromium.) Further notes on the practice of casting against chills will be given later in this article.

It has been known for some time that important load-carrying castings such as gears, cams and crankshafts develop maximum strength in carefully melted, alloyed, low carbon (2.80% C) compositions possessing a hardness range of 220 to 280 Brinell. This combination of strength and hardness is not always important; dies, brake drums and minor machine tool parts are alloyed in higher carbon types of irons solely to possess a wear resisting structure and a high hardness. Castings in commercial production which require moderate alloying additions are usually similar in nature to those previously mentioned for small alloy additions, yet with considerably thicker sections. Examples are heavy duty gasoline engine parts, diesel and steam engine castings, heavy gears, cams, crankshafts, camshafts, dies, rolls, mining machinery, valves and pumps handling abrasives.

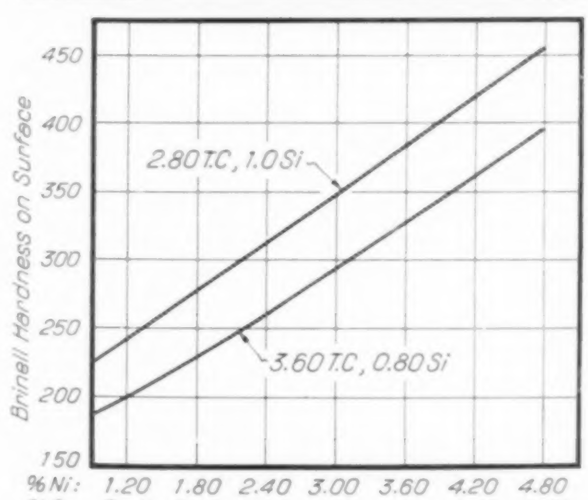
Large Alloy Additions for File-Hard Dies

Nickel-chromium additions in the range of 4 to 6% are frequently employed to develop maximum machinable hardness in heavy castings. In this case it is desirable to work with compositions low in silicon and preferably not too high in carbon.

Gray iron has been described, for simplicity's sake, as a steel interspersed with graphite. Unfortunately, gray iron structures differ from steel not only because graphite is present, but because silicon is dissolved in the iron in substantial amounts. Silicon is a powerful graphitizer. More or less abruptly it unbalances the normal tendency for an iron-carbon alloy to solidify with practically all of its carbon fixed in combination with iron as carbide, and precipitates graphite not only during solidification but during the subsequent slow cooling. The net result is that instead of a fully pearlitic "steel" body, a matrix with 0.30% carbon or even less may result.

Cast steel, on the other hand, whether it contains 0.10% C, or 0.50% or 0.90%, and whether the section is ¼ in. or 8 in. thick, will solidify with a fairly uniform distribution of its carbon as carbide, since it contains an ineffective amount of silicon. Nickel can be added to steel in large amounts with results somewhat in opposition to those just described for silicon; the matrix is strengthened, toughened, hardened and the properties at the core of heavy sections evened up.

These facts are well known and have been utilized in various ways. Sipp and his co-workers, in their patented preheated mold process for obtaining fully pearlitic iron, insist on low silicon iron and recommend that nickel be used to obtain the necessary degree of graphitization and uniformity in structure. Piwowarski expresses the same thought in his 1934 paper in *Transactions* of American Foundrymen's Association, in referring to the "insensitivity" of irons



An Extension of the Data Given in the Diagram on the Opposite Page to Cover Sections From 1x4 In. to 4x4 In., When the Analysis Is Balanced as to Carbon, Silicon, Nickel and Chromium

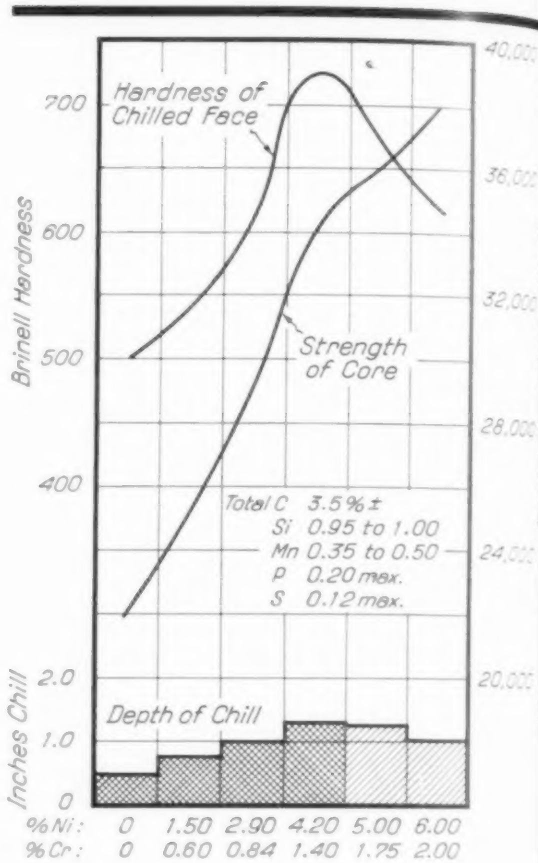
alloyed with nickel to changes in section, or to variations in their cooling rates.

Hurst notes the same thing in a diagram in *The Iron Age*, Oct. 26, 1933, showing a hardness survey from surface to core of 4-in. round bars with increasing nickel content. These were quenched in oil from 1600° F.; the bars containing 1% nickel or less had a gradual decrease in hardness of 140 to 200 numbers, edge to center; the bars containing 2 to 4% nickel dropped 110 numbers in the outer shell, and the 2-in. central core was practically uniform.

The effect is obviously a manifestation of the ability of nickel, either alone or with certain other alloys, to retard the transformation rates of gamma to alpha iron. Thus, it has been established that the critical cooling rate for maximum hardness of plain 0.80% carbon tool steel is approximately 300° F. per sec. The rate for a 3% nickel steel practically free from silicon is approximately 30° F. per sec., and if other alloys such as molybdenum or chromium are included, this rate may be reduced to as low as 6 to 10° F. per sec. It is obvious then that slowly cooling, heavy sections require substantial amounts of nickel along with other alloys and a low silicon content to harden them efficiently during the normal course of cooling in the mold.

One of the best examples of the application of this principle is found in the production of file-finished dies. In this case the foundryman, aware that the product will be relatively hard and difficult to machine, prepares a mold in which the part corresponding to the working face of the die is rubbed down and repeatedly black-washed to a smooth, slick surface. The mold is then poured to yield a minimum amount of distortion or warpage. The casting is shaken out and the working face rubbed down with emery cloth, filed, and the fins trimmed, and thus made ready for work with little or no machining.

Other castings hardened by the use of large alloy additions are cams, crankshafts, gears, metal and clay working dies, pump and valve parts subjected to abrasion, mine and quarry castings such as chutes, chute boxes, classifier blades and cement mill castings.



While Nickel Alone Suppresses Chill (White Fracture at Surface), Combination With 1/4 to 1/3 as Much Chromium, Gives a Harder, Deeper Chill

Nickel Reduces Chill Tendency in 2x4-In. Blocks of Car-Wheel Type Iron. Deep chill at top of plain iron is not machinable, but 5% nickel iron, without chill yet equally hard, is machinable

No Nickel *1% Nickel* *2% Nickel* *3½% Nickel* *5% Nickel*

Chill Casting

Steel men are expert at surface hardening by pack-hardening or carburizing to produce a high carbon case which attains a high hardness of approximately 600 Brinell when heat treated. The foundryman has a short cut for all this! He molds the required shape in sand, then inserts a metal block or chill on such surfaces as require extreme hardness, then pours an appropriate composition of cast iron into the cavity. All surfaces in contact with the chill emerge from the mold unmachinable and very hard (about 450 Brinell).

Railroad car wheels have been made this way for generations. Years ago, in an effort to avoid the use of expensive char-

Average Tests of Chilled Plain and Ni-hard Irons

	Plain Iron		Ni-hard	
	High Carbon	Low Carbon	High Carbon	Low Carbon
Total carbon	3.50	2.75	3.50	2.75
Silicon	0.75	0.75	0.75	0.75
Nickel	—	—	4.50	4.50
Chromium	—	—	1.50	1.50
Brinell hardness of chilled surface	500	400	650 to 700	575
Tensile strength in chilled section, psi.	†35 to 40,000	*48 to 53,000	*55 to 60,000	*70 to 80,000
Tensile strength in gray core, psi.	16 to 25,000	22 to 39,000	30 to 35,000	40 to 50,000

† Calculated from transverse tests
* A.S.T.M. tensile test pieces ground from chilled blocks

coal iron, roll makers turned to alloys, and ended by producing tougher, stronger and harder chilled iron than had ever been made before. In the small castings field, auto specialty shops commenced to alloy the chilled iron to toughen and harden it for such parts as valve lifters or tappets. History in these fields seems to repeat itself.

The ability for nickel additions in the range of 2 to 10% to harden a gray iron progressively had been established for some time, as well as the fact that it eliminates chill. The significant fact that the chilled portion hardened rapidly, even though the thickness of chill (as determined by a silvery layer in the fracture) was less and less with increasing nickel contents, remained worthy of attention. Ultimately a nickel-chromium composition now known under the trade name "Ni-hard" came into being. It was first described by the present writer before the American Institute of Mining and Metallurgical Engineers in 1933, from work done in collaboration with T. J. Wood and F. S. Kasch of the Bayonne Research Laboratory of International Nickel Co. It generally contains approximately 4.5% Ni and 1.5% Cr, balanced to maintain chill depth and develop a stronger, tougher, harder, finer grained iron which was much more resistant to wear, heat and corrosion than its chilled iron companions of equivalent base composition. The diagram and table at top of these facing pages compare it with its plain cast iron companions. In cases where only the skin is to be chilled and hardened the gray backing can be made machinable by limiting the alloy content along the lines indicated in former diagrams.

Conveying machinery, pulleys, sprockets and wheels requiring that hubs or projecting flanges be machinable, must be alloyed with less than one-half the Ni-hard nickel-chromium content recommended above. The diagram at bottom page 15 gives the expected degree of hardening in the gray and unchilled zones of such castings.

The fully alloyed composition of Ni-hard is usually non-machinable not only over its chilled surfaces but also throughout its gray portions behind the chills. Surfaces must be dressed by grinding. Some exceptions to this occur in high carbon, low silicon, low chromium variants which become sufficiently softened in their gray portions to permit slow but effective machining.

Highly Alloyed Iron Liner for Gas Engine Cylinder. Broken to Show Chill at Top Where Piston Rings Rub Back and Forth. Hardness at the chilled section is 850 Vickers

The preceding diagrams, as well as the table on page 80, illustrate that compositions low in silicon and chromium and high in carbon and nickel can be depended upon to be machinable in gray zones yet very hard in chilled zones (up to 600 Brinell). Material of this type is being developed for various kinds of roll service where the machinability of roll necks is an important factor.

The opportunity to produce chilled cam tips up to 700 Brinell with machinable bearings (Brinell less than 350) awaits the attention and requirements of the automotive industry. Compositions containing 3.00 to 3.75% total carbon, 0.70 to 1.20% Si, 3.5 to 4.5% Ni, 0.90 to 1.10% Cr with 0.40 to 0.75% Mo, cast close to finished dimensions, offer attractive possibilities for parts requiring both hardness and toughness.

The engine cylinder liner

(Continued on page 80)

Letters to the Editor

Grain Size Vs. Draw Temperature

PORTSMOUTH, VA. — Metallurgical literature has recently been full of statements about the effect of grain size on the properties of heat treated parts, but most of these statements are of a qualitative nature. On the opposite page is a data sheet showing in a *quantitative* way how to adjust the drawing temperature of heat treated forgings of plain carbon steel (S.A.E. 1050) for a specified hardness. Similar charts may be advantageously prepared for other analyses and other heat treatment programs.

Before the construction of this chart each batch or furnace load had to be wholly or fractionally drawn and redrawn until the desired Brinell values were obtained. A draw that was 100% successful for one batch was 100% wrong for the next one. The problem was a serious one, economically and metallurgically. A careful investigation showed that, in each instance, the furnace conditions and operations were unvaried, the pyrometers correct, the heaters abundantly experienced, the Brinell machine in good adjustment, and the testing procedure uniform.

It seemed like splitting hairs to attribute the varied response of this steel to the slight variations in carbon and manganese generally permissible in the S.A.E. 1050 composition. And yet, after these three variables — carbon, manganese, and the drawing temperature — had been studied in relation to one another, a definite correlation was found to exist between the amount of these elements present and the drawing temperature. Thenceforward the drawing temperature was predicted accurately seven out of every ten times.

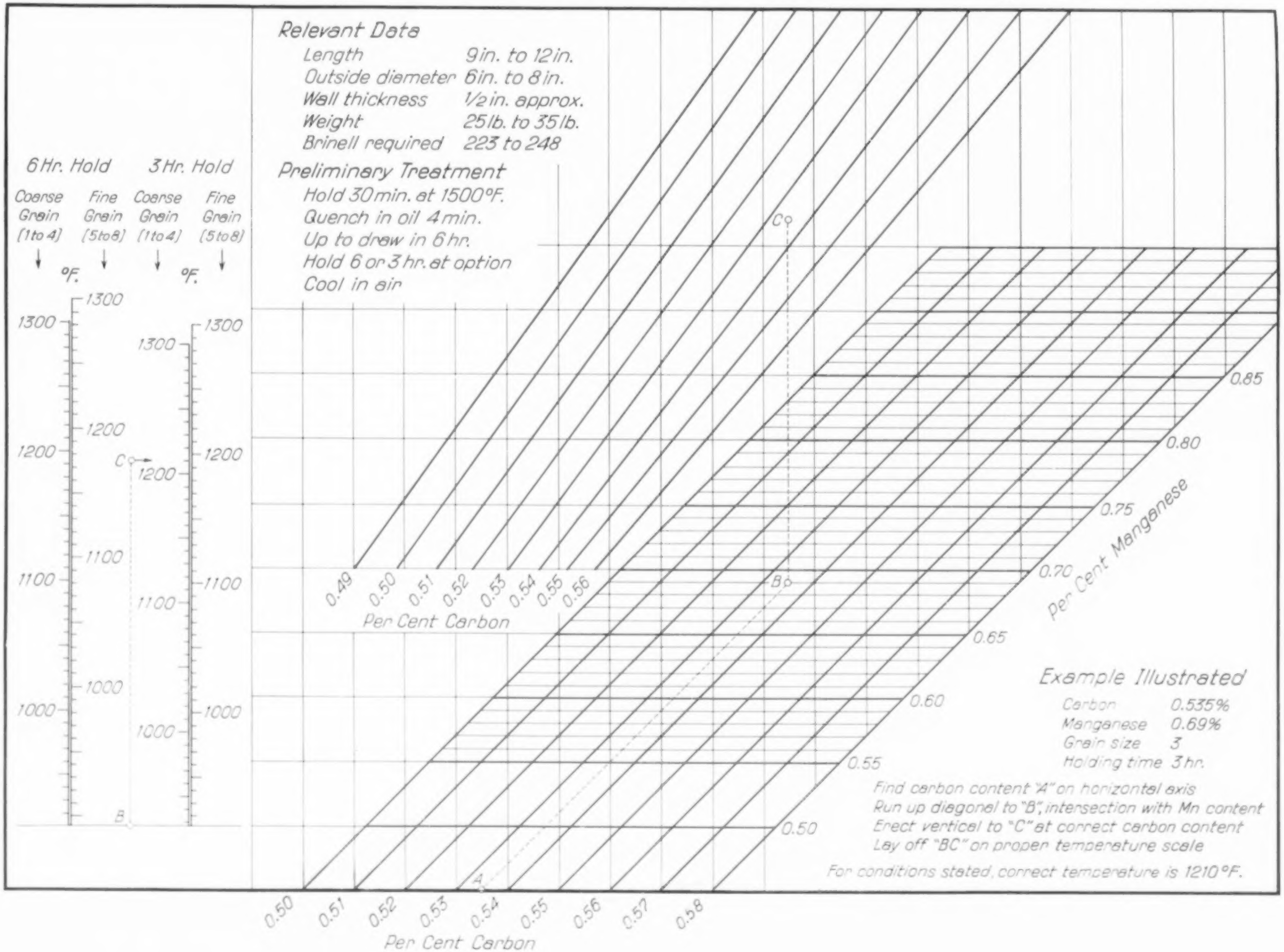
It was believed that this percentage could be bettered if the number of forgings comprising a furnace load were constant. Such was not the case. What this practice did do, however, was to narrow down the spread or dispersion of results, making them more nearly the same hardness.

At this stage it was decided to determine the effects of inherent or McQuaid-Ehn grain size on the Brinell hardness of this steel with respect to the drawing temperature after an oil quench at 1500° F. It is practical knowledge that a coarse grained steel, because of its slow reaction characteristics, is essentially deep hardening, while fine grained steel, because of its high reaction speed, is shallow hardening. The fine grained steels are defined as those whose grains lie in the range of size from No. 5 to 8 (A.S.T.M. chart), and the coarse grained steels ranged in size from No. 1 to 4.

The results of this study enabled the almost completely accurate forecasting of drawing temperatures. If it were not for ingot segregation and for the occasional variation in McQuaid-Ehn grain size from ingot to ingot of the same heat of steel, it is believed that a 100% correct forecast could be obtained.

The effect of each of the five variables — carbon, manganese, McQuaid-Ehn grain size, holding time, and temperature — upon the Brinell hardness of S.A.E. 1050 steels is graphically shown on the chart on page 49. This graph is the essence of voluminous data gathered over an extended time and from the testing of some 50,000 forged cylinder barrels made from some 50 different heats of steel. In this work it was found that an error in drawing temperature as small as 10 to 15° F. up or down is sufficient to throw the Brinell heavily over to the soft or hard side respectively.

Draw Temperatures for S.A.E. 1050 Basic Steel Forgings



Similar charts for the same steel but for lower Brinell hardnesses show that higher drawing temperatures blunt, and if high enough, merge almost indistinguishably the effects of each of the five variables. The temperature leeway for consistent hardness then widens to 20 to 30° F. and perhaps even more.

JOSEPH A. DUMA

Thickness of Galvanized Coating

MIDDLETOWN, OHIO — Those who preserve their copies of METAL PROGRESS or file the useful data sheets, should correct an error in the September issue, page 49. Due to carelessness in our laboratory the photographs sent the Editor were marked 100 ×, whereas the magnification is really 1000 ×. This correction should be made in order that no one may have a mistaken idea of the thickness of galvanized coating on ingot iron sheets.

H. P. MUNGER

Steels for Ball Bearings

GROSNY, U.S.S.R. — From other countries we frequently hear doubts expressed as to our ability to industrialize our nation— essentially an agricultural and stock raising one. Clear evidence on this point may be drawn from our success in the mass production of ball bearings — they being machine parts certainly requiring modern machinery and skilled workmen for their successful manufacture.

The government factory in Moscow was completed three years ago. Its 1935 production, together with the small plant which formerly belonged to S. K. F., the well-known international organization, amounts to 20,000,000 ball bearings in 126 types. Since the estimated annual consumption in 1937 will be 45,000,000 bearings, work is already under way to double the scheduled capacity in Moscow and to construct a second large plant in the town of Saratov. Most of the 4000 machine tools required will be made in our own machine shops. The staff at the enlarged Moscow works will number about 35,000 persons, and 350 types and sizes of ball bearings and roller bearings will be produced.

The requisite steel has also been definitely planned. Much discussion among our metallurgists brought out the advantages and disadvantages of two main types: The chromium steels containing 1.0% carbon and the case hardening nickel-molybdenum steel used principally in America. It was concluded to base our standards on the high carbon, chromium steels used by the Swedish S. K. F. This firm relies principally on three grades of chromium steel for ball and roller bearings. Alloy content varies with the size of the part, but chromium is depended on for the hardening element rather than manganese or carbon, which are kept relatively constant. The grades are as follows:

Grade SKF-9. Chromium 0.40 to 0.60%, for balls smaller than 0.350 in. diameter.

Grade SKF-13. Chromium 0.85 to 1.10%, for balls between 0.350 and 0.700 in. (Chromium on the low side for the smaller balls.)

Grade SKF-3. Chromium 1.40 to 1.65%, for rings and balls larger than 0.700 in. diameter.

Some Italian firms recommended the use of five different grades of steel, differing only in chromium content from 0.50 to 1.45% Cr.

The Soviet standard now calls for four high grade alloys to be made either in electric furnaces or acid open-hearth (or in certain basic open-hearths where melting practice is under close control). The designation shows the median chromium content:

Cr-6 has 0.45 to 0.75% chromium and is for cold forged balls less than 0.300 in.

Cr-9 has 0.75 to 1.05% chromium and is for cold forged balls from 0.300 to 0.550 in. diameter, and hot forged balls up to 0.800 in. diameter.

Cr-12 has 1.05 to 1.40% chromium and is for balls made from bars larger than ¾ in.

Cr-15 has 1.30 to 1.65% chromium and is for rings, cups and cones, and solid rollers.

In all the above carbon is 0.95 to 1.10%, manganese is 0.20 to 0.40%, silicon is 0.15 to 0.35%, sulphur less than 0.020%, phosphorus less than 0.027% and nickel less than 0.20%.

There is also an intermediate grade of steel, Cr-10, for hollow rollers of the Hyatt type. This may be made in basic open-hearth furnaces. It is of lower carbon, and its analysis is as follows: C, 0.30 to 0.42%; Cr, 0.80 to 1.20%; Mn, 0.40 to 0.70%; S, less than 0.030%; other elements as listed above.

Ball and roller bearing steel is now being manufactured at three of our steel plants: Electro-Steel in the Moscow district, Zlatoust works in the Ural district, and Zaporog works in the Ukraine. Total production was 6500 short tons in 1932 (the first year), 17,000 short tons in 1933, and 35,000 in 1934.

B. M. SUSLOV

Polishing of Cast Iron

Moline, Ill. — Several metallographers have recently published methods for the polishing of cast iron, with special reference to the retention of the graphite. Any one who is confronted with the problem would be only too happy to follow the longest procedures if rewarded for his labors, but numberless trials convinced the undersigned that trouble was encountered in removing scratches from a fine polishing paper by work on a rotating disk.

Various mediums were tried with the hope that the number of intermediate steps and the time required for final polishing could be reduced. At this time we turned to the paraffin disk devised by Guthrie and described in *Transactions* in March, 1925.

Guthrie, however, was interested in reducing the amount of amorphous or ferritic film so that a uniformly etched surface could be obtained, he having found that a hard structureless base was necessary to reduce or eliminate entirely this film. With this paraffin disk and a suitable abrasive Guthrie has done very fine work on steels.

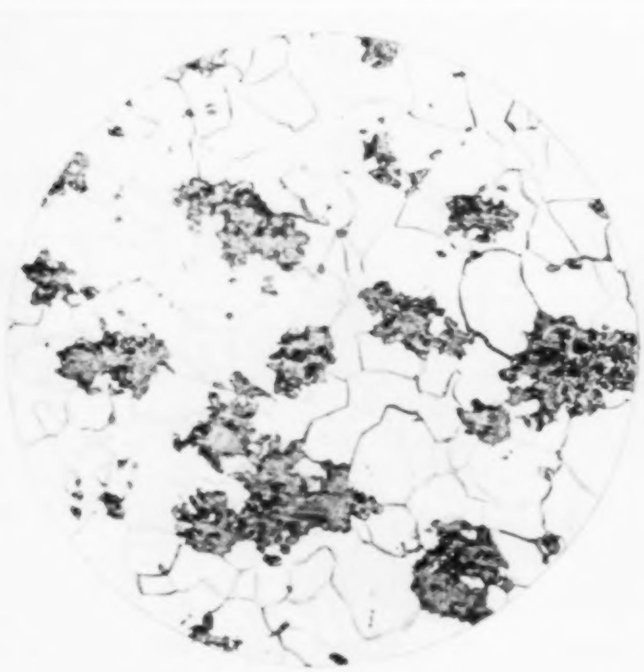
These considerations indicated that cast iron could be polished in this way so as to disturb a minimum of metal and avoid the production of metallic films which conceal the true structure. Considerable experimentation led to the following modification of the usual polishing methods for preparing cast iron specimens. By using only four steps in the operation, excellent results have been obtained:

1. Grinding on alundum wheel (120 mesh) to remove saw marks and secure a flat surface. Wheel speed approximately 1250 r.p.m.
2. Grinding on wheel covered with No. 0 emery paper. Wheel speed about 1250 r.p.m.
3. Polishing on disk covered with paraffin, using levigated alumina suspended in liquid soap (glycerin base) solution. Speed about 650 r.p.m.
4. Polishing on disk covered with silk satin, using magnesium oxide paste worked well into the fabric and just enough water to prevent dragging of the sample. Speed about 350 r.p.m.

A word should be said about the final polishing. It may be omitted if visual examination under the microscope without photography is all that is required. Otherwise use the dull side of the cloth; this avoids roughening.

Accompanying micros are representative of the work. In cast iron we are dealing with graphite, a soft and friable constituent, embedded in ductile ferrite, relatively hard pearlite, and a phosphide eutectic which polishes about the same as pearlite — a difficult combination.

Louis Ziffrin



Malleable Iron, At Left, Polished by Special Technique, and Etched With 1% Picral. 200 X. Commercial cast iron, shown at right, has a complex structure containing softest graphite and relatively very hard pearlite and phosphide eutectic

Time and Temperature for Maximum Age Hardening

TEDDINGTON, ENGLAND — In his recent series of articles in METAL PROGRESS, Dr. Merica has made clear the great interest which is being shown in age hardening alloys and the fact that now the age hardening alloy appears to be the rule, not the exception. Whereas 20 years ago the phenomenon was considered in relation to a single alloy of aluminum which was hardened on exposure at room temperature, there are now hundreds of known age hardening alloys, which are hardened at a variety of temperatures. Except in the light alloy field, where age hardening provides the only means of fulfilling the requirements of aircraft specifications, it cannot be said that the alloys at present available are sufficiently outstanding to warrant more than specialized and consequently restricted application. One bar to the confident use of age hardened alloys in some applications is that there is no positive evidence that the state of maximum hardness is the most satisfactory in regard to resistance to fatigue, creep and service stresses.

As regards theory, it is certain that age hardening is a result of the tendency of bodies consisting largely of supersaturated or otherwise unstable solid solutions to proceed towards thermodynamic equilibrium. In cases where the solid solubility relationships are such that supersaturation is brought about by rapid cooling, the subsequent hardening is often described as "precipitation hardening" although there is usually no microscopic or X-ray evidence of a precipitate in the hardened alloy. Unquestionable evidence of precipitation can be obtained when such an alloy is softened by prolonged aging at a sufficiently elevated temperature. According to some writers a critical aging temperature separates temperatures at which no precipitate forms and hardening is permanent, from the higher temperatures at which precipitation will occur, and hardening is followed by softening. An alternative view is that aging is merely hastened by increase in temperature, and consequently proceeds to a later stage within the reasonable duration of experiment. It has therefore appeared desirable to analyze the effect of temperature on age hardening.

The data in the literature and those obtained from the recent study at the National Physical Laboratory (see Jenkins and Bucknall, *Journal*, Institute of Metals, Autumn 1935) of a nickel-silicon-copper alloy that was capable of age hardening within a wide temperature range, indicate that curves plotting hardness against the logarithm of the duration of aging are generally of a common type, namely a steady rise to a flat maximum followed by a steady fall; the maxima of such curves are progressively displaced towards shorter times as aging temperature is raised. At high temperatures the curves experimentally obtained show a steady fall from a high hardness and at low aging temperatures a steady rise. This study showed that where a peak hardness value was attained the trend of the attainable hardness was upward as temperature decreased; for a given period of aging the optimum temperature is that at which full hardening is just reached within the period.

The matter was further examined by plotting the available data on charts whose ordinates were a logarithmic time scale and a temperature scale, the divisions of which were proportional to reciprocals of degrees, absolute. Specific heat treatments being represented at points on the chart, it was found that a straight line could be drawn which represented the division between specimens which were hardening from those which had hardened and were subsequently softening. Sufficient examples of this relationship between time and temperature of attainment of maximum hardness have been found to make probable its general validity; such examples are afforded by aluminum alloys of the duralumin, lautal and straight copper types, by beryllium-copper and nickel-silicon-copper alloys and by the β-brasses. In the last named case the published information also indicates that the electrical resistivity, which passes through a maximum during aging, reaches peak values at times similarly related to temperature but which are consistently a little shorter than those for the hardness maxima.

The equation of the straight line, $t = C \epsilon^{\frac{m}{T}}$, where T is the temperature and t the time, is similar to that established by Dushman and Langmuir, Dunn and others for diffusion in the solid state. This is highly significant since, as Merica has pointed out, the early stages of aging, generally described as "cluster formation" clearly involve diffusion of the stranger atoms from their original lattice positions. Since any later stage,

(This letter continues on page 78.
More correspondence on next page.)

European Specifications for Heavy Welding

TURIN, ITALY — The interesting editorial "Heavy Welding Abroad," which appeared in the June issue of METAL PROGRESS, suggests a few remarks concerning the recent evolution of European specifications for welded structures of considerable magnitude.

Its statement that "continental operations seem to be influenced more pronouncedly by German practice and opinions" is quite true, and this explains many features of various European specifications for welded structures. Very often these have followed the evolution of the official German specifications.

In Germany as in other countries every project involving large construction must be submitted for preliminary official examination to an appropriate technical bureau. The first official German instructions for welded structures was published in July, 1930. At that time, no practical information was available concerning the behavior of welded steel structures; as a consequence those first specifications based mainly on analytical calculations had to be very conservative. On the basis of subsequent study of actual structures those specifications appeared to be too restrictive, and were revised. In fact three revisions of the specification have already appeared, one in May, 1931 (DIN 4100) the second in July, 1933, and the third in July, 1934.

It would take too long to detail the modifications introduced in the specifications by these successive revisions. To confirm what has been said above, it will be sufficient to quote three figures: For butt welds carrying bending stresses, in the 1931 specifications the load allowed in the structure was 0.60 of the permissible stress in the structural steel. This coefficient was raised to 0.75 in 1933, and to 0.80 in 1934. This last edition of the specification authorizes an even higher coefficient when practical tests show that it is admissible.

Austrian specifications have followed the German, and the 1934 Austrian edition is very similar to the 1933 German edition.

Belgian and English specifications are similar to each other. Unlike the German specifications, they do not include methods for the analytical calculation of stresses. The first official English specifications published in March, 1934, permit butt welds in tension, and a coefficient of 0.85 for the ratio of the load on the weld to the permissible stress in the steel.

The evolution of the Italian specifications has followed a line similar to the Belgian, in that it is based more on the results of practical experience than on preliminary analytical calculations. However it is interesting to note that notwithstanding the different lines followed in the development of the various European specifications, the final conclusions do not show noticeable differences.

Specifications for the electrodes vary widely in the different European countries, despite the fact that, with very few exceptions, nothing but coated electrodes are used.

German specifications for electrodes include tensile, impact and bending tests. The Belgian and English specifications include a tensile test on test bars made entirely of deposited metal. The minimum tensile strength fixed by the latter specification is 63,000 psi. and the minimum elongation 20% on a length 3.54 times the diameter of the test bar.

The qualification tests for welders vary even more widely in the different countries.

FEDERICO GIOLITTI

Huey Test for Corrosion Resistance

BARBERTON, OHIO — A corrosion test for "stainless" metals proposed by W. R. Huey has been widely used in various laboratories, and is now finding its way into purchase specifications. Since some of these set an acceptance limit close to the ultimate corrosion resistance under the best conditions of heat treatment, it is desirable to determine the reproducibility of this test, so that different appraisals of the same steel may be avoided.

The test is conducted by immersion of properly prepared samples in 65 to 67% nitric acid contained in flasks equipped with reflux condensers, maintained at boiling temperature for 48 hr., after which the samples are withdrawn, washed, dried, and weighed. Usually at least three such periods are required by the purchase specifications to establish the corrodibility of a resistant material.

Some work in the research department, Babcock & Wilcox Co., utilized $2x\frac{3}{4}x\frac{3}{16}$-in. samples of an austenitic stainless steel plate known to have good resistance to nitric acid. Analysis was 20% chromium, 10% nickel and 0.06% carbon. Data were given in full to the last meeting of the American Society of Naval Engineers. First it was found that if less than 700 c.c. of acid was used for an exposed area of 10 sq.in., the total

penetration increased. This same effect was observed when acid was used longer than 48 hr., thus proving that the amount of acid in relation to the surface area is important, as well as the accumulation of corrosion products in the corroding solution. Initial concentration of acid should also be 67% or higher, as weaker concentrations gave low values.

Likewise considerable variation in test results on a particular sample may occur due to the use of acids from different manufacturers, and slight variations are due to the use of different lots from the same manufacturer. The presence of traces of certain impurities such as hydrochloric and sulphuric acids or salts of iron, nickel, chromium, and other metals may cause variations out of all proportion to the amount present.

It thus appears that whenever a rigid specification for weight loss must be met it is important to use the purest acid obtainable, and to provide at least 70 c.c. of concentrated acid for each square inch of surface exposed.

JOHN L. MILLER

Faraday, the Metallurgist

CHICAGO, ILL. — I have long been an admirer of Michael Faraday, and consequently have noted with satisfaction the tribute paid to him in the October issue in the short article that refers to Faraday as the maker of the first alloy steel.

It happened that I was in correspondence with Sir Robert Hadfield a few years ago when preparations were being made in London for holding the Faraday Centenary Celebration. Sir Robert's keen interest in Faraday's metallurgical researches prompted him to engage F. J. Halnon, a well known British sculptor, to make the design for a commemorative plaque, and a pattern was made from this design for the production of some castings in the steel foundry operated by Hadfield's Ltd. in Sheffield.

I was fortunate enough to be presented with one of these cast plaques. It is about 8x13 in. in size, and shows in relief the figure of Faraday in his primitive laboratory. On the right is the box, labelled by him, in which 79 specimens of steel were discovered, and on the left is the "blast furnace" in which he made the alloys. The metal in the cast plaque contains approximately 22% chromium, 7% nickel, and 4% tungsten and the casting is a very fitting tribute to Faraday, who probably was the first experimental producer of alloy steels, and who undoubtedly was the originator of the electrical equipment which constitutes the fundamental feature of the latest (electric) furnaces used for making steel. And the casting also is an example of the fine work done in the Hadfield foundry. This may be evident from the attached photograph of the plaque in my possession.

Plaque Cast in High Chromium-Nickel-Tungsten Steel, Commemorative of Faraday's Researches in Alloy Steels

R. A. BULL

* * *

EDITOR'S NOTE — The results of extensive studies on these first alloy steels are contained in Sir Robert Hadfield's most interesting book, "Faraday and His Metallurgical Researches," published by Chapman & Hall, London, W.C.2, England. Proceeds from the sale of this book go to maintain research at the Royal Institution, where Faraday lived and worked for so many years.

An extended abstract of one of the important papers presented before the International Acetylene Association convention in Cleveland in November. Columbium is a semi-rare metal, but adequate supplies of American ore are being developed

Columbium in Welding Rods for Stainless Steels

Several problems had to be solved before high chromium and stainless steels could be welded satisfactorily. Not only is the element chromium easily oxidized when molten, but the oxide is very infusible and it will act as an insulating blanket between the oxy-acetylene flame and the work. A flux with a high solvent power is essential; careful flame control, minimum puddling, and no excess heating will keep the amount of chromium oxide low.

An oxidizing flame would remove chromium from the metal as chromium oxide and produce unsound, brittle welds. Excess acetylene — a reducing flame — would form chromium carbides, which also would remove valuable chromium from the metal. The most satisfactory flame is therefore a strictly neutral one.

Furthermore, many points have to be borne in mind relating to the metallurgy of the high alloy steels themselves. These can be discussed in two headings.

Steels Containing 4 to 7% Chromium

Welding — These steels are air hardening; therefore the weld metal and particularly the zone adjacent would be hard and brittle unless the welding had been done on preheated parts and the joint subsequently annealed. Since air hardening is due to chromium carbide, a search was made for other elements with a more marked affinity for carbon and which would lock up that troublesome element in a harmless form. For this the two semi-rare elements columbium and titanium are particularly effective.

By W. J. Priestley
Vice-President, Electro Metallurgical Co., New York

Becket and Franks have already presented a paper before the American Institute of Mining and Metallurgical Engineers showing that chromium steels with titanium and columbium additions are soft and ductile even in the as-rolled condition. Welding properties, naturally, are also improved. We have found that most satisfactory work is done with a welding rod containing 6 to 8% chromium, carbon under 0.10% and columbium six to eight times the carbon.

The presence of either columbium or titanium also reduces the annealing time to minutes instead of the hours often required for steels not bearing these elements, and marked improvement in ductility results from a simple blowpipe anneal to a red temperature (1475 to 1650° F.) for one or two minutes. The softening range varies from 1300 to 1650° F.

Some typical results are as follows: Oxy-acetylene welds were made in ¼-in. annealed plate of the following analysis: 5.50% Cr, 0.07% C, 0.56% Mo, 0.37% Ti. As welded the joints had 30,000 to 40,000 psi. yield strength, 55,000 to 65,000 psi. breaking strength, 4 to 8% elongation in 2 in., and 45° to 90° free bend. After a blowpipe aneal, companion welds had the same strength but elongation had increased to 8 to 12% and the angle of free bend was 120° to 180°

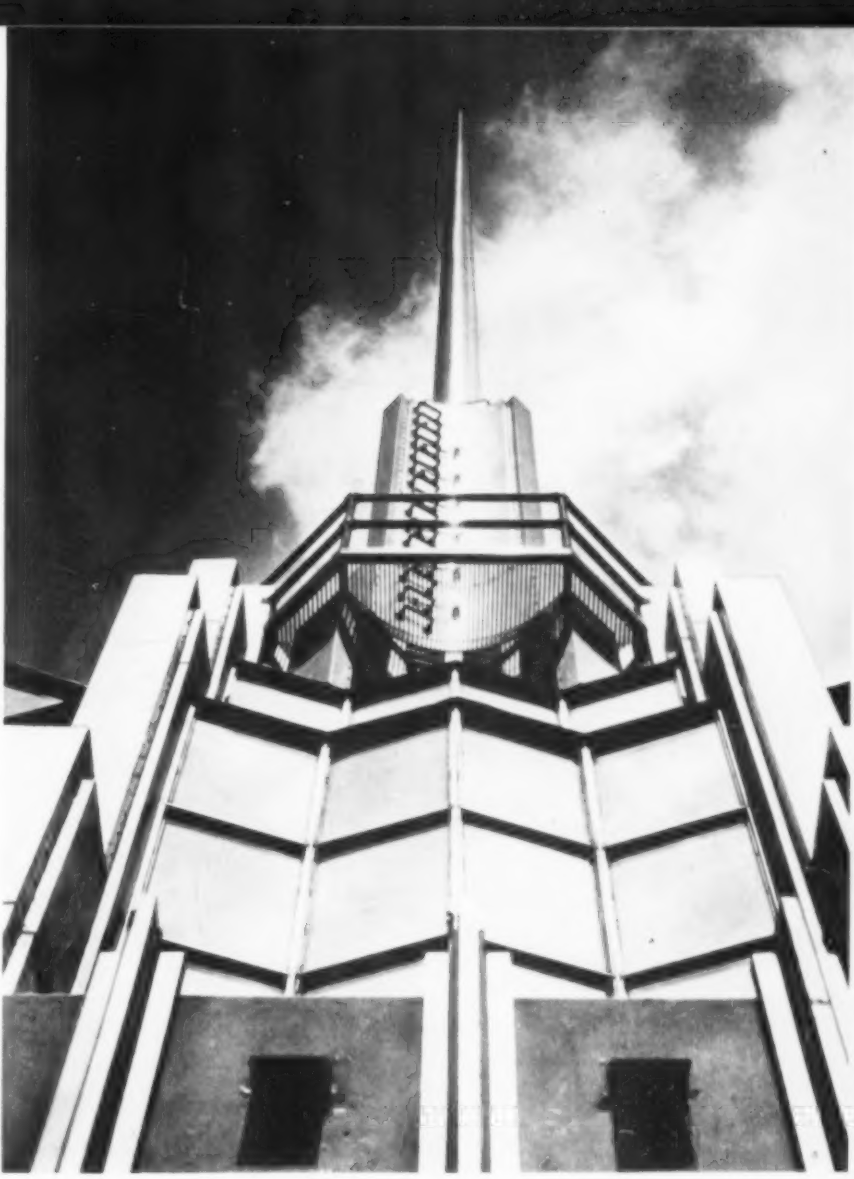
— which is an extremely satisfactory figure.

Cutting — Foundrymen, making castings of this chromium steel, are sometimes confronted with a problem if they remove gates and risers from the casting by oxy-acetylene cutting. To prevent air hardening and subsequent cracking, the usual procedure is to preheat the entire casting to about 900° F., at which temperature the steel is quite ductile. If the preheat is too high the entire casting may harden during subsequent cooling in air. In other instances, the risers are cut from dead annealed castings; this may develop hard spots, and the casting must be re-annealed.

Columbium or titanium in the analysis overcomes most of these difficulties. Titanium, however, may introduce certain casting difficulties which it is believed can be eliminated by the use of columbium.

Cutting the higher chromium and chromium-nickel steels may be done by the flux method, which consists in clamping soft steel plates on either side of the work to provide enough iron oxide and molten iron to flux away the more infusible chromium and nickel oxides. This may be accomplished also by holding an iron rod in the cut.

Naturally these methods take more heat than is used in cutting ordinary steel and the heating effect on the stainless steel is apt to render it susceptible to intergranular corrosion, as noted below, unless the steel contains a stabilizing element.



Gleaming Flagpole of Stainless Steel, Welded, Surmounts Cities Service Building, New York, Rising From a Grand Finial in the Modern Architectural Style. Photo by Wurts Bros.

Austenitic Steels

The welding problem encountered in the low carbon, chromium-nickel austenitic steels, of which the 18% chromium, 8% nickel is typical, is likewise due to carbon but to a quite different metallurgical effect. In these steels corrosion resistance is impaired by the formation of carbides along the micro-grain boundaries, and penetration occurs along these intergranular surfaces. The chromium-nickel steels, as purchased, have been processed by the maker to a homogeneous, corrosion resistant, solid solution microstructure. However, when they are reheated to a temperature within the approximate range of 500 to 1400° F., a new constituent (usually thought of as chromium carbide) forms along grain boundaries, robbing the adjacent metal of chromium and thus lowering its corrosion resistance.

During welding, the weld metal is heated above this critical temperature range and then fairly rapidly cooled through it, and there is insufficient time for precipitation of much if any of the new constituent in the weld metal. However, the base metal in a zone close to and parallel to the weld remains heated within the 500 to 1400° range for a sufficient length of time and cools at a rate slow enough so that carbides precipitate.

The weld metal itself, while relatively free from corrosion susceptibility from the above cause, often decreases in corrosion resistance due to carbon pick-up from the welding flame.

Presumably anything that would lock up the carbon in these steels would improve their properties, and today a considerable tonnage of stainless steel designed for severe operating conditions contains either columbium or titanium. They serve as a stabilizer for the carbon and prevent the damaging structural changes between 500 and 1400° F. The harmful effect of welding heat on

Oxy-Acetylene Welds in 18-8 Plate, As Welded

Addition Elements		Tensile Properties of Joint			Free Bend Test
In Plate	In Welding Rod	Yield Strength	Ultimate Strength	Elongation in 2 In.	
none	none	39,200 psi.	76,500 psi.	22%	180° no cracks
0.98% Cb	0.81% Cb	37,200	75,400	20	180° no cracks
0.47% Ti	0.81% Cb	41,000	75,500	17	180° no cracks

the zones adjacent to the joint is therefore eliminated, and heat treatment after welding is unnecessary to secure full corrosion resistance.

Since little columbium is lost during the operation, it is more satisfactory to use a welding rod containing columbium than one with titanium, regardless of what stabilizing element is used in the base metal. Columbium does not complicate welding with the oxy-acetylene flame. The free-flowing characteristic of the columbium treated 18-8 rods makes them ideally suited for this practice. Columbium is further beneficial since it counteracts the 0.02 to 0.04% carbon which is picked up. The accompanying table gives the tensile and bend tests on welds in ¼-in. plates, tested as welded. The base metal contained approximately 18% chromium, 9% nickel and 0.07% carbon with or without addition elements as shown. The welding rod was of the same type analysis, and in the second and third instance had about 0.80% columbium. (The amount of columbium necessary varies from 6 to 10 times the carbon content of the steel, depending upon the use for which it is intended.) It will be seen that the addition elements necessary for stabilization in the 500 to 1400° F. temperature range do not harm the tensile properties.

Columbium in the welding rod necessitates no changes in welding procedure. The principle of a neutral flame and sufficient flux should be strictly followed. With columbium treated plate and rod, backhand welding can be utilized to avoid distortion; with this technique, the weld metal and adjacent zones are held at a dull red temperature longer than by the usual forehand method. This longer time at temperature need not be feared when columbium bearing plates and rods are used, since the welding zone is amply protected against the precipitation of dangerous carbides.

Endurance of Spring Wire With Ground Surface

By E. T. Gill and R. Goodacre

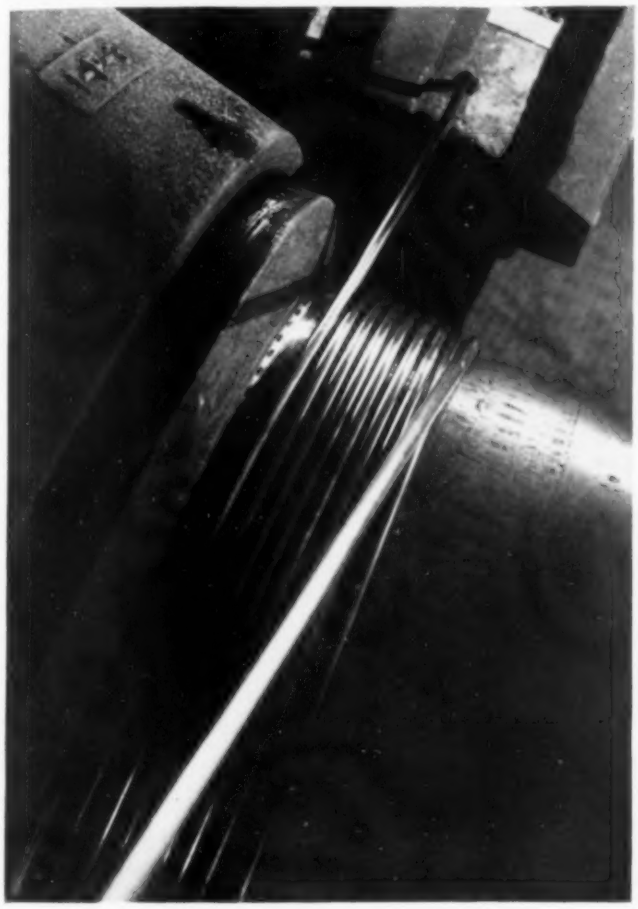
Condensed from Journal of the Iron & Steel Institute

Studies on spring wires have been considerably facilitated by the perfection of the Haigh-Robertson fatigue testing machine. The wire sample requires no expensive preparation; one end fits a sleeve in a thrust bearing, the other a chuck fitted to an electric motor spindle. The length of the wire is bowed out by end-thrust into the form of a curve, and is simultaneously caused to rotate at high speed by the electric motor. Eventually, after a number of revolutions dependent upon the stress (that is, the amount of bow), the wire breaks at or very near the center of its length, which is the position of maximum stress.

Another important feature of the machine is the rapidity with which the tests can be carried out. At a motor speed of 18,000 r.p.m., it is quite possible to obtain data for a full S-N curve in 24 hr.; this includes an overnight run of some 15 to 20 million stress reversals.

Some data on 0.79% and 0.86% carbon steel wire will be given, these being analyses commonly used for valve springs for airplane engines. When made up into a spring, the wire is subjected to torsional stresses, and it has been assumed up till recently that the ratio of torsional to tensional fatigue (based on the consideration of the relationship of shear stress to tensile stress) does not hold in the case of wire. However, a study of the results in this research makes it seem very probable that the fatigue limit in bending will give a good indication of the torsional fatigue properties of polished spring wire as determined in careful researches by others.

Wire rod used in this study was patented from 1850° F. in lead at 900° F., then 0.020 in.



This Very Striking View of a Wire-Drawing Block Was Taken by Margaret Bourke-White for Russell, Burdsall & Ward Bolt & Nut Co.

ground from the surface to remove decarburization. Ground rods were selected of such size that when drafted given amounts the wires would all be 0.080 in. diameter. Limiting fatigue stress of patented wires with thin (about 0.002 in.) decarburized skin, cold drawn 75% (which gives optimum all round properties) is very close to ±51,500 psi. irrespective of carbon content in the wire, and consequently the fatigue properties in reverse bending appear to be mainly those of the ferrite skin. When the skin breaks down due to fatigue, the remainder of the wire also fails, probably owing to the concentration of stresses set up at the original crack. In 0.79% carbon wires without soft skin, drawn 75% reduction, the limiting fatigue stress is ±78,000 psi. This figure is increased to ±83,000 psi. if the drawn wire is machine polished and almost ±90,000 psi. if further polished (buffed) with 000 emery.

When an optimum point of reduction by cold working of wire is passed the torsional values and contraction of area begin to decrease very rapidly and the tensile strength increases unduly. This amount of cold reduction required to produce "overdrawing" is higher in the lower carbon wires (with the usual decarburized skin), than with high carbon spring wires. A like anomaly exists in curve of fatigue properties versus draft when a wire is overdrawn.

In the case of wires drawn free from decarburization, it was found that although the curves of tensile strength versus amount of reduction were similar to those of the corresponding decarburized wire, the limiting fatigue strength increased steadily (and in some cases after 75% reduction, more abruptly) in a similar manner to the tensile strength curves. In other words a high carbon wire, free of decarburization, is relatively insensitive to overdrawing — at least as far as shown by a lowered endurance limit.

Interesting data were also secured on the endurance of spring wires, free from decarburization, after low temperature tempering (20 min. in the range of 300 to 750° F.). It is generally suggested that the optimum temperature for this type of heat treatment lies between 400 and 500° F. for cold drawn, plain carbon steels. Endurance limit of the 0.79% carbon wire, drawn 50%, is ±72,000 psi., and after tempering at 400° F. is ±83,500 psi. (Corresponding figures for the 0.86% carbon wire are ±74,000 psi. and ±91,500 psi.) This improvement takes place on wires drawn up to approximately 60% reduction, but beyond this point a change always takes place. In many cases the limiting fatigue stress of the tempered wire falls below the value for the as-drawn, untempered condition; with those which do not fall below this value the limiting fatigue stress is only slightly raised.

In the 0.86% carbon steel there are distinct signs that it is overdrawn after a reduction of 82%, because the limiting fatigue strength in the as-drawn condition decreases after this point and there is very little recovery after tempering.

High values of the limiting fatigue stress may be obtained under certain conditions. 0.79% carbon steel, when drawn to 85% reduction and tempered at 300° F., gives a maximum value of ±93,000 psi. In the case of the 0.86% carbon steel a maximum of ±101,000 psi. is obtained with 78% reduction after tempering at 400° F. When it is pointed out that none of the last mentioned specimens tested was in a polished condition — that is, the wires would still contain slight draw marks and defects — it seems rather amazing that such high values should be obtained. Polishing can result in a further increase.

Recent Important Books

Metallography

METALLOGRAPHY AND HEAT TREATMENT OF IRON AND STEEL, by Albert Sauveur. Fourth edition, 19th thousand. 531 pages, 7x10½ in., 425 illustrations. McGraw-Hill Book Co., New York, and The University Press, Cambridge, Mass. Price $8.

THAT A STEADY DEMAND exists for a technical work throughout a quarter of a century proves uncommon merit, beyond the praise or blame of a mere reviewer. Professor Sauveur's book is, indeed, the American standard text. When comparing the present edition in detail with the third (1926), numberless changes, additions and deletions are found. The text has evidently been completely reset, but the publishers are to be criticized for not insisting that the diagrams be redrawn to uniform style, to match their high typographical ideals.

Two or three short chapters are new, but some old material has been omitted here and there so that the size of the book is unchanged. Numerous lines of work of seeming importance developed during the last decade are mentioned rather briefly — perhaps too briefly — but on the other hand Sauveur is doubtless better able to bring them into proper perspective than others of us, more readily impressed by the magnitude of near-by things.

His statement of the fundamentals of metallography would be hard to improve, and really that has been the chief value of the book and undoubtedly will continue to be. These fundamentals are quite stable and independent of current manufacturing and fabrication practices and it could well be argued that a textbook on metallography might properly confine itself to fundamentals and generalities and not attempt to keep up with specific operations. Any textbook by its very fixity is bound to lag behind ever-changing practice, but if a book does attempt to correlate theory with practice, the practical end should be carefully revised whenever the book is reprinted. In practical matters lies the chief deficiency of this book; much could be done to modernize the pages on the properties of the alloy steels now commercially exploited.

While Dr. Sauveur in his introduction warns the reader that many statements will be found differing from views expressed in former editions, he still champions beta iron, and even though members of the younger generation do not agree with him, they respect his gallant defense. One suspects that the trenches are being breached, however, for here and there is found the expression beta ferrite, which might be interpreted "beta alpha-iron." At another place he also abandons an impregnable citadel (where beta iron is defined as a non-magnetic substance, body-centered cubic in crystallinity) and throws out a not very impressive sortie in suggesting that the tetragonal lattice in quenched steel be called beta iron (page 267).

As might be expected from his letter to METAL PROGRESS last month, he views with a cold and fishy eye recent proposals to eliminate troostite and sorbite from the metallographical dictionary. Text matter on these transition constituents is reprinted practically without change. An important new Chapter XVIII on "A Simplified View of the Hardening of Steel, of

the Transition Constituents and of the Microstructure of Steel" may be studied with profit, and is an extended statement of the views contained in the above-mentioned letter.

Since all book reviews tend to magnify small defects found in everything of human origin, this one will end by saying that the excellences of this work by the Dean of American metallographers are Himalayan by comparison!

• • •

THE THIRD EDITION of R. S. Williams and V. O. Homerberg's "Principles of Metallography" (McGraw-Hill Book Co., New York, $3.50) suffers by comparison and is disappointing. Although 50 pages have been added to the text, the chief defect of the second edition has been retained — namely, engravings, paper and press work that are wholly inadequate to reproduce photomicrographs, even of average quality.

No matter how extended may be the definition of the word "metallography," the center of the field must always be the observation and recording of structures of a wide variety of metallic alloys, both ferrous and non-ferrous; hence this matter should have first place in a book of this title. Since these structures (and the corresponding properties) are modified by composition, melting practice, heat treatment, hot and cold work, and various types of intelligent use or ignorant abuse, the teacher of metallography finds himself branching out into all phases of metallurgy — physical, chemical and physico-chemical. Obviously this is too much for 300 5½x8-in. pages, so the authors must be very sketchy in many of their statements.

They also are best when sticking close to the center of the field. For instance, their Chapter V on macroscopic examination is the best and most complete statement in print (even if highly condensed). Unfortunately the same cannot be said of their account of alloy steels. For example, no mention is made of the single quench for carburized stock. Likewise, this reviewer wants to scream when he sees the ancient Guillet's "constitutional diagram" for alloy steels printed and reprinted, just as though there has been no more accurate work done in the last 30 years. The authors also overlook the exceedingly fine work of Messrs. Dix, Keller and Wilcox on the identification of the score of constituents found in aluminum alloys — alloys of rapidly increasing importance, commercially.

High Purity Iron

THE METAL IRON, by H. E. Cleaves and J. G. Thompson, 574 pages, 6x9 in., 113 illustrations. Published for The Engineering Foundation by McGraw-Hill Book Co., New York. Price $6.

THIS IS THE SIXTH of the monographs of the Alloys of Iron Research to appear. Former ones have been enthusiastically reviewed in these columns, and this latest addition matches the excellence of its predecessors. In fact, it is distinctly improved in readability, the authors putting in many interesting sidelights and making less effort to compress their material into telegraphic style.

About one-quarter of the text is devoted to a discussion of various methods of purifying iron. It appears immediately that pure iron has not yet been approached as close as 99.99%, although the determination of numerous impurities existing to 0.001% or less is another unsolved problem. Degasified electrolytic iron 99.9% pure is relatively easy to get; this and open-hearth ingot iron 99.8% pure represent the raw materials used in most work on so-called pure iron. (In reality it is iron of only reasonably high purity.)

Aside from being a useful starting point for fundamental metallurgical investigations, *pure* iron is most interesting for its magnetic properties. Whereas a maximum permeability of 14,000 was had in the purest iron of 1914, Yensen of Westinghouse and Cioffi of Bell Telephone Laboratories have vastly improved this, Cioffi's most recent achievement being 280,000. The ultimate value cannot be predicted and awaits the production of large single crystals of iron, free from lattice distortion due to chemical impurity or to mechanical or thermal strains. Much of the literature on ferromagnetism has to do with magnetic theory, and is not reviewed in this volume, for few physicists have made a serious attempt to find out the fundamental numerical data. In this line, as in much other scientific metallurgical work, published investigations are difficult if not impossible to interpret and correlate because the experimenter failed to describe the history of his specimens, or to determine their chemical composition and physical structure accurately. Hence widely different physical data are sometimes reported for material simply described by the experimenter as "electrolytic iron."

Sixty pages are devoted to the chemical properties of iron — that is, its corrodibility — an extremely interesting chapter, valuable to any student of corrosion. There is a voluminous literature (much of it highly controversial and based on assumed, or at least unproven, properties of pure iron) on the relative corrosion resistance of electrolytic iron, ingot iron, wrought iron and low carbon steel. The authors close the chapter with the sapient remark: "Corrosion resistance of iron may be summarized in two words — iron rusts."

Basic open-hearth ingot iron is of such large commercial importance that the chapters on mechanical properties and heat treatment and aging will be particularly interesting to users of high grade sheet metal. These hundred pages are only typical of the fact that a book which on first thought would appear to be interesting to a relatively few researchers in physics or metallurgy actually contains a great deal of information applicable to many industrial problems.

Alloy Steels

The Manufacture and Application of Molybdenum Steels, by Julius L. F. Vogel and W. F. Rowden. 103 pages, $6\frac{1}{2}$ by $9\frac{1}{2}$ in., 49 illustrations. The Kennedy Press, Manchester 1, England. Complimentary copies through High Speed Steel Alloys, Ltd.

This book, written by two of the ablest alloy steel men in England, briefly covers the manufacture of molybdenum steel, and goes into some detail concerning the properties and applications of these steels as produced in England. The American reader will find the sections on manganese-molybdenum and chromium-nickel-molybdenum steels of particular interest, since they are of types that are not extensively used in the United States.

The property of molybdenum in eliminating temper embrittlement is very forcibly brought out in this book, which gives charts showing the susceptibility of various alloy steels not containing molybdenum to impact brittleness after slow cooling from drawing or annealing heats. The English take much more stock in impact tests than they do in elongation and ductility figures, because the former figure measures toughness in addition to normal ductility.

The book is well illustrated with interesting pictures taken at many famous English steel plants, and contains much information which will be of value to any steel metallurgist who wishes to know more about molybdenum in particular, and foreign steel practice in general.

C. M. Loeb, Jr.

* * *

Bethlehem Steel Co. has issued two reference manuals of unusual quality, one on Alloy Steels and the other on Steel Plates. These are bound in fabricoid, 6x9 in. page size, each about 360 pages, and are for complimentary distribution. The manual on alloy steels will be especially useful since it contains a large number of charts showing tensile properties after various heat treatments. Next is a discussion of the various steels applicable for specific uses, and for the specific industries. Finally comes a series of short sections on the effect of various fabrication processes on the properties of the steel, on methods of test and inspection, and on standard specifications and tolerances — altogether a most complete compendium.

More and Better Welding

Procedure Handbook of Arc Welding Design and Practice, Third Edition, 596 pages, 6x9 in., 714 figures. Lincoln Electric Co., Cleveland. Price $1.50.

Distribution of this book has been phenomenally large, and proves (if any proof be needed) the widespread interest in welding as a fabrication process. Two large editions were exhausted in exactly two years, and this third edition is enlarged by some 140 pages. The price charged is nominal, in the sense that it probably is less than engravings, printing, paper and binding of such a large volume.

While the work is intended for welding operators as well as supervisors, designers and engineers, the amount of space devoted to technique is relatively small, hardly 10% of the book. The most value comes to men responsible for welded construction; there are 400 pages of text devoted to design of machine parts and building frames, and a multitude of pictures of successful work, much of it quite complicated.

Anyone merely paging through the book would be impressed with the essential correctness of a welded joint in practically all places where a fixed joint must be made between simpler units. Or, put it another way; the observer wonders what uses the screwed, bolted or riveted joints would now have if the electric welding process had been known in Bessemer's day.

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Of all the services of the telephone there is none more important than this—helping you to make friends and to keep them.

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Thus the bonds of friendship are formed and strengthened. Greater happiness comes into the widening circle of your life. Some one, somewhere, says sincerely—"It was nice of y o u to call." This day, a voice-visit by telephone may bring reassurance to some friend who is wondering how you are.

More and more are people turning to Long Distance to carry friendly voices across the miles. They like its speed, clarity, intimacy and low cost—especially after 7 P.M., when calls by number to most points cost about 40% less than in the daytime.

BELL TELEPHONE SYSTEM

Francis B. Foley

Bachrach

Chapter Chairmen

A. S. M. 1934-35

James M. Hutton

W. A. Welcker, Jr.

E. J. P. Fisher

Bachrach

Raymond T. Porter

Francis B. Foley

Frank Foley, chairman of the Philadelphia Chapter in 1934-35, was graduated from Girard College, entered the art department of a newspaper, reformed quickly, and then started off in a metallurgical career as a clerk and door-puller in the open-hearth department of the Midvale Steel Co. That was in 1905.

Two years later he was promoted to the Research Staff and remained at Midvale until 1917. Between 1917 and 1926, when he returned to the company, he engaged in varied activities.

First he accepted Sam Hoyt's invitation to assist him in teaching metallography at the University of Minnesota, but in 1918, when almost everyone was drawn into the War, he became a member of the War Materials Investigation Group of the U. S. Bureau of Mines and in 1919 headed the Iron and Steel Division of the Bureau at Pittsburgh. As a Bureau metallurgist, he had the privilege of collaborating with the late, famed Dr. Henry Marion Howe for a year, and then returned to the Bureau to engage in research in drill steel for mines and oil wells. Blast furnace research work was next in order for the Bureau of Mines at Minneapolis and at Rolla, Mo. In 1924 he was metallurgist for the Lucey Mfg. Corp. in Chattanooga and two years later returned to the Midvale Co. as superintendent of research, where he has remained to this day.

Voigt Proctor

Mr. Foley joined the A.S.M. about 15 years ago — that is, very early — and has from time to time acted as chairman of technical sessions and has addressed a number of the chapters on technical subjects. He is also a member of the American Institute of Mining and Metallurgical Engineers, the British Iron and Steel Institute, and the American Chemical Society.

James M. Hutton

James Muer Hutton, born in Glasgow, like all true Scots is an inveterate traveler and takes European tours with as little concern as most of us step into our automobiles for a 50-mile spin down country and back. (Continued on page 66)

Sinbad's Burden

. . . Yielding to the pleadings of the Old Man of the Sea, Sinbad lifted him onto his shoulders and carried him tenderly across the stream. To his amazement, the Old Man refused to alight. Instead, he entwined his legs so tightly around Sinbad's chest that he could not be shaken off. Day after day Sinbad's burden became more and more crushing. . . .

A MATERIAL, process or modus operandi will sometimes so firmly imbed itself in the construction of an implement, appliance, engine, machine, vehicle, or part, that discarding it in favor of something more modern is often difficult. Meantime, its continued use may become a serious burden to both production and sales departments. . . . For competition is ever ready to capitalize a rival's lack of progressiveness.

Is the persistent retention of once modern steels threatening to leave your company behind in the face of the newer discoveries of metallurgists and steel-makers? Have you brought yourself up to date on the latest progress of Molybdenum — the alloy which not only improves ordinary carbon steel, but actually increases the effectiveness of other alloys?

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Investigate Moly. Moly has had more than a decade of countless laboratory, steel-furnace, foundry, forge and punishing service tests. We invite engineers, metallurgists, production and business executives to write for either or both of these interesting books: "Molybdenum in 1934" and "Molybdenum in Cast Iron — 1934 Supplement." Also ask us to mail you our periodical news-sheet, "The Moly Matrix." Be free, too, to enlist the aid of our Detroit experimental laboratory. Climax Molybdenum Company, 500 Fifth Avenue, New York.

MOLY

CLIMAX Mo-lyb-den-um

INDUSTRY'S MOST MODERN AND VERSATILE ALLOY

Personalities

Mr. Hutton received his education in Scotland and England and keeps up to date by continuous study at American universities. During the World War he was comptroller of parts of scientific instruments for the Allied Navies. Later he was foundry superintendent of a branch of the General Electric Co. at Coventry, England. In this country he was superintendent of the Atlas Die Casting Co., Worcester, Mass., before joining the Precision Casting Co. at Syracuse, N. Y., where he has been metallurgist for nine years.

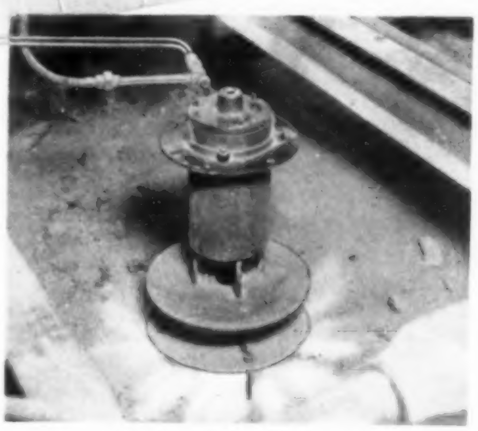
In addition to the American Society for Metals, Mr. Hutton is a member of the British Institute of Metals and a number of other technical societies. He has served the Syracuse Chapter as vice-chairman and chairman and has attended all of the National Metal Congress meetings for the past nine years.

As a Scotchman, Mr. Hutton brags about the fact that he buys third-class passage for ocean travel and uses a first-class cabin. We don't know how he does it, but we hope none of the steamship officials will read this!

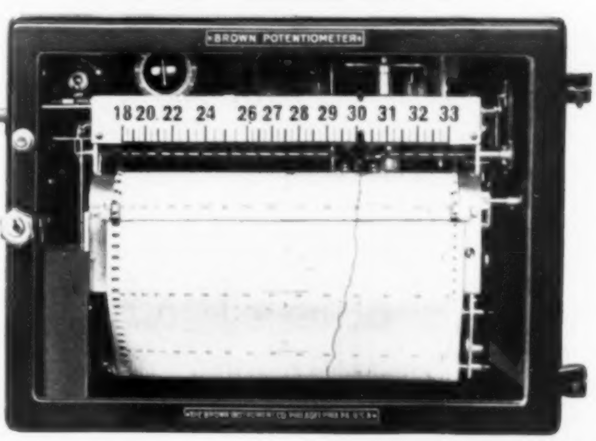
W. A. Welcker, Jr.

William A. Welcker, Jr., first saw the light of day at Roanoke, Va. Satisfying an early military tendency, he did plenty of "squads east" at Virginia Polytechnic Institute while preparing to receive a B.S. in Mechanical Engineering in 1926. The sunny south claimed him for two more years, while in maintenance and operation work for the Viscose Corp. of Virginia, and as assistant chemist for the Norfolk and Western Railway. He rode the rails all over the East for the N. & W., inspecting and testing various railroad supplies. By reason of his foundry control work and testing of gray iron, steel, and non-ferrous castings, he helped keep the line out of the red — no small accomplishment!

When Mr. Welcker came north, it was as an engineer specializing in electrolysis for the study of underground corrosion at Columbus, Ohio. In 1929 he joined the staff of Battelle Memorial Institute as research engineer, a position he still holds. He has several papers to his credit in the field of low temperature testing and endurance work, and is much interested *(Cont. on p. 68)*



Brown Radiation Pyrometer Unit installed on Open Hearth Roof connected to Recorder for First Helper.



Brown Potentiometer Pyrometer with Automatic Fuel Cutoff.

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YOU can't take chances on excessive furnace roof temperatures. It is too costly. Overheating not only damages furnace roofs but also multiplies shutdowns for patching, and increases fuel consumption per ton.

Brown Potentiometer Pyrometers installed on open hearth or heating furnace roofs enable you to hold roof temperatures below the danger line—get more heats per campaign—reduce repair and fuel costs per ton—insulate with safety.

Temperature measurement by means of Radiation, Tuyere Type or Imbedded Thermocouples—Recording, Signalling or Automatic Fuel Cutoff—All are available in Brown Open Hearth Roof Temperature Systems to meet individual plant requirements and preference.

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BROWN POTENTIOMETER PYROMETER
AND
MINNEAPOLIS-HONEYWELL CONTROL SYSTEMS

To Measure and Control is to Economize

Personalities

in the testing of bearings and in heat treatment. He excels as a "gadgeteer" and photographer.

Bill has been a member of the Executive Committee of the Columbus Chapter for several years, served as vice-chairman and finally as chairman in 1934-35.

E. J. P. Fisher

Mr. Fisher fails to disclose what E. J. P. stands for, but does admit that he is familiarly known as "Bud" or the standardized nickname "Alphabet." Born of American parents in Berlin, Germany, in 1900, he claims he crossed the Atlantic three times before finally being settled in New Jersey at the age of two.

His B.S. in chemistry was awarded for surviving four years at Worcester Polytech. Postgraduate work in metallurgy under Prof. William Campbell at Columbia's School of Mines further prepared him for his start in the business world in 1921.

His first job was as melter and metallurgist for a budding die casting company in Worcester. The economic "frost" of 1922 (not his melting practice) closed this first episode and led to a series of experiences (jobs to you) including successive connections with General Electric Co. at Harrison, N. J., R. Wallace and Sons Mfg. Co. at Wallingford, Conn., Carpenter Steel Co. and Diamond Chain & Mfg. Co. at Indianapolis, Hubbard Steel Foundry at East Chicago, and finally Keystone Steel & Wire Co. at Peoria, Ill., where he was physical metallurgist until a recent change to Republic Steel Corp., where he is metallurgist with the rod and wire division, Chicago district.

Bud is a member of many technical societies, was director and head of the Metallurgy Section of the Peoria Academy of Science, and captured the first Wire Association Medal for his paper on "Cold Drawn Spring Wire."

He is a veteran of many A.S.M. chapter associations, having joined the New Haven Chapter in 1923, served the Indianapolis Chapter as treasurer and chairman, transferred to the Chicago Chapter, and finally assisted in the organization of the "baby" Peoria Chapter in 1934. He was immediately elected the first chairman.

(More biographies on page 70)

Personalities

Raymond T. Porter

Ray Porter was introduced to the forging industry under the guiding hand of his father, then superintendent of the Heppenstall Co., Bridgeport, Conn. The paternal idea was that a start when young did no harm, so during his high school years young Porter spent Friday nights and summer vacations operating a lathe in the machine shop of the Heppenstall Co. When he finished high school in 1918 the lure of hot metal under the hammer and press had so drawn him that he worked for three years in the forge department as hammersmith.

He was then transferred to heat treating and in 1923 was placed in charge of that department as well as of the physical testing of materials. In 1932 he entered the sales department — the present location of many a good technician.

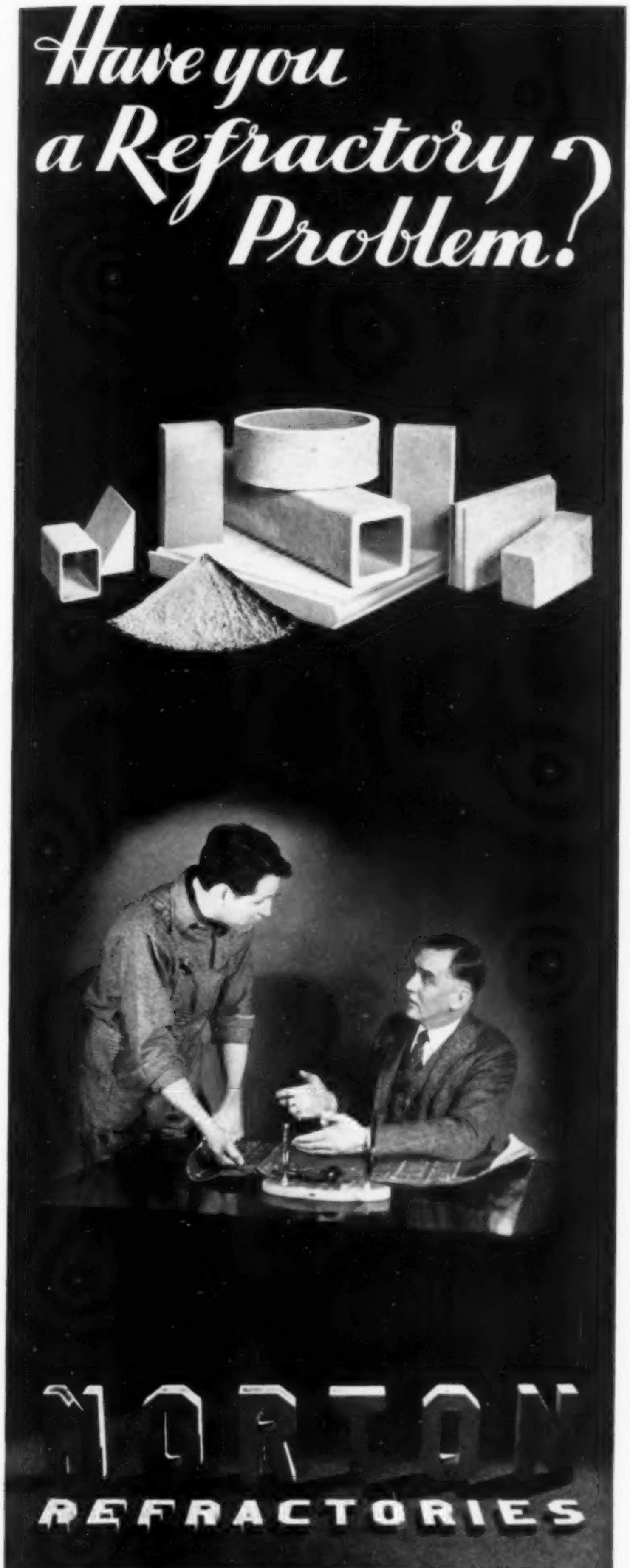
Mr. Porter joined the New Haven Chapter in 1927 and served on the executive committee for three years. He became chairman in 1934 after serving as secretary, and vice-chairman.

Voigt Proctor

Born in Pittsburgh and therefore completely surrounded by steel mills, Voigt Proctor nevertheless had no intention of entering the steel business when he studied engineering at Pennsylvania State College.

His first job was as industrial engineer for Pittsburgh Plate Glass Co. He next worked for Armstrong Cork & Insulation Co. and was eventually sent to Chicago to sell cork board to the packing plants. But the odor of the Stock Yards made him homesick for the steel mills and brought him the realization of where his future lay. He therefore moved back to Pittsburgh and started selling tool steel for Colonial Steel Co.

Some of the first heats of stainless steel were then being made by Allegheny Steel Co. and the possibilities of this remarkable material so inflamed his imagination that he took a job selling the new stainless. This led to a position in the special steel department of Joseph T. Ryerson & Son of Chicago. When a similar department was organized in Cincinnati, Mr. Proctor was sent to take charge of it. Hence he became chairman of the Cincinnati Chapter last year.



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Cements and bonded shapes for all types of induction furnaces—large and small — for melting ferrous and nonferrous metals.

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Free Literature

Heat in Industry

"Wherever Heat Is Used in Industry" is the title of Surface Combustion Corp.'s new booklet which starts with "Surface Combustion" principles and shows a part of various types of standard burners and furnaces and special furnaces. Bulletin Dx-51.

Progress in Pipe

A 16-page, 2-color folder released by Republic Steel Corp. lists and describes the various types of tubular products manufactured by Republic and its subsidiary, Steel & Tubes, Inc. It is indexed for added convenience. Bulletin Dx-8.

Airless Cleaning

Comprehensive coverage of abrasive cleaning and preparation methods by description and illustration is contained in a colorful book published by the American Foundry Equipment Co. It describes the airless abrasive cleaning and preparation method known as "Wheelabrating." Bulletin Dx-112.

Solvent Degreasing

The effectiveness and simplicity of the new methods of solvent degreasing are remarkably well demonstrated in a booklet by Rex Products and Mfg. Co. Machines are available for the vapor, immersion, and spray methods used either singly or in combination. Bulletin Dx-111.

Tubing Weight Tables

Timken Steel & Tube Co. has issued a series of "Master Weight Tables" for round steel tubing, on letter size heavy paper, punched for binding. Weights per lineal foot of length are given for all sizes of hot finished and cold drawn tubing. Bulletin Mx-71.

Everdur

Properties, applications, and forms available of this copper-silicon-manganese alloy are described by American Brass Co. High strength and corrosion resistance, ductility, weldability, workability, and moderate price are some of the advantages featured. Bulletin Dc-89.

Aluminum Alloys

Working facts on aluminum — the properties and heat treatment of both cast and wrought alloys — are briefed for the manufacturer and designer in a booklet by Aluminum Co. of America. An appendix gives tables of physical properties, forms and sizes available. Bulletin Dc-54.

Nickel Silver

Seymour Mfg. Co. has a folder which gives the story of nickel silver—its historical background, preferred composition, applications, shapes available, and modern method of manufacture. Bulletin Ax-48.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Stainless Steels Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Metallograph

A new 36-page booklet of E. Leitz Inc., contains all information on the Leitz large Micro-Metallograph MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Pyrometer Drive Unit

For installations where their potentiometer control pyrometers are to be used singly, the Foxboro Co. has developed an improved type of motor drive unit. A new bulletin describes this unit and gives complete details regarding Foxboro potentiometer controllers. Bulletin Ox-21.

Annealing Coiled Strip

How G-E bell-type furnaces for bright annealing coiled steel strip produce a uniform, high quality product is told by General Electric Co. in Bulletin Jyx-60.

Refractory Cements

The control of heat in many industrial processes depends upon refractory materials that may be sprayed, painted, poured, trowelled, or rammed into position. Norton cements for these purposes are described in a booklet which has an appendix giving tables and miscellaneous information of great value to furnace operators. Bulletin Ox-88-A.

Vanadium Facts

Revived after nearly 20 years is the house organ of Vanadium Corp. of America, "Vanadium Facts." This paper shows considerable thought and care in its preparation and contains valuable and interesting information on vanadium steels. Bulletin Ox-27.

Carburizing Steel

High strength and ductility, forgeability, and machinability, combined with superior case carburizing properties, permit the attainment of maximum production with minimum cost. Such properties are obtainable in Jones & Laughlin's Jalcase steel. Bulletin Mx-50.

New Homo Furnace

The new Homo furnace described in a bulletin issued by Leeds & Northrup provides for even tempering on a very dense load. Automatic control includes a feature that prevents overshooting. Fine tempering on extra dense loads at low cost is provided. Bulletin Mx-46.

Metallographic Methods

"WACO Service" suggests application of the newer methods to daily routine. Included are the new bakelite specimen mount, low cost polishers and grinders, and an offer of sample Selvyt polishing cloth. Wilkens-Anderson Co. Bulletin Ox-7.

Hardness Conversions

International Nickel Co. has a handy, celluloid, vest-pocket-size hardness conversion table, which quickly gives approximate relation between Brinell, Rockwell and Shore hardness values and corresponding strengths of nickel alloy steels. Bulletin Nx-45.

Metameter

Information on Bristol Co.'s metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Castings for High Heat

The compositions, properties and uses of Driver-Harris Co.'s Nichrome, Chromax, and Cimet, and other alloys for high temperature and corrosion resistance are given in a new illustrated folder. Bulletin Nx-19.

No-Contact Control

A book which should be in the hands of every man interested in temperature reading and control is the Data Book published by Thermo Control Devices, Inc. which describes a line of indicating and controlling pyrometers with Wheelco no-contact system of control. Bulletin Dx-110.

New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive nonoxidizing furnace atmosphere and their new, continuous brazing, coppering and soldering furnaces. Full details are given in Bulletin Ar-30.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Tool Room Furnace

A new type of lining and onevalve control are two of the features of the American Gas Furnace Co.'s new tool room oven furnace that would make it economical to replace many older furnaces now in operation. Fully described in Bulletin Ox-11.

Alloy Castings

A new bulletin on corrosion and heat resisting alloy castings is offered by Michiana Products Corp., manufacturers of Fire Armor and Zorite and other heat and acid resisting castings. Bulletin Jyx-81.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue by asking for Bulletin Ax-4.

Centrifugal Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Rotoblast

A new blast cleaning machine eliminates the need for compressed air as the abrasive driving agent. Pangborn Corporation tells how a rapidly spinning wheel propels the abrasive by controlled centrifugal force. Bulletin Ox-68.

Machining Handbook

This little handbook giving machining properties and a great deal of other related data for a wide variety of steels should be of much value in aiding the steel user to select the right steel for the right purpose. Union Drawn Steel Co. Bulletin Ox-83.

Welding Metallurgy

J. H. Critchett, vice-president of Union Carbide & Carbon Co., has prepared an exceptionally informative discussion of the physical and chemical principles involved in the oxy-acetylene welding of steel. Bulletin Ayx-63.

Air-Operated Controllers

The simplicity and outstanding performance of Brown Instrument Co.'s new Air-o-Line air-operated controllers, with their interchangeable control units and "ready-at-hand" adjustments, make them a revolutionary contribution to a large range of diversified industries. Bulletin Ox-3.

High Tensile Steels

Three types of high tensile steel particularly adapted to the transportation industries are described in a folder from U. S. Steel Corp. These are a chromium-copper-silicon steel for corrosion resistance, a medium manganese steel, and a strong structural silicon steel. Bulletin Mx-79.

Silico-Manganese Steel

Silico-Manganese steel for heavy duty springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Turbo Compressors

The new items in Spencer Turbine Co.'s bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Metal Progress
7016 Euclid Ave., Cleveland

Please have sent to me without charge or obligation the following Literature described in the December issue. (Please order by number only.)

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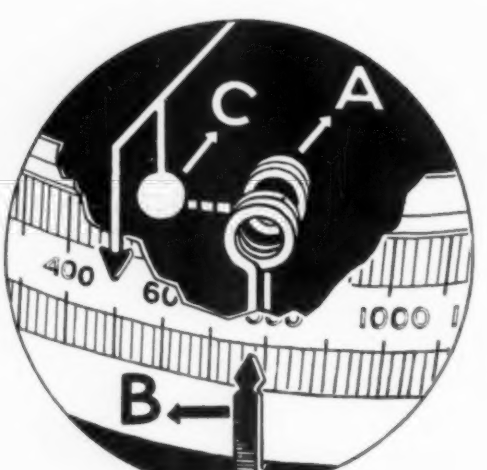
should be in the hands of every man interested in temperature reading and control . . .

The WHEELCO No Contact System of Temperature Control introduces a radio principle which does away with all mechanical devices in the control instrument, obviating the use of cams, gears, depressor bars, etc.

We offer a line of indicating-controlling pyrometers with the WHEELCO No Contact System of Control *as low as $90.00.*

The WHEELCO Limitrol is an entirely new instrument. It is an indicating pyrometer and a temperature limit control that will operate an alarm and shut off the furnace, if desired. The Limitrol will function with your present control equipment as a protective device. It will shut off the furnace in case of broken thermocouple or the failure of your regular control equipment. The saving of one batch or load will often pay for its installation. *Price $75.00.*

The Limitrol with automatic switch will automatically indicate the temperature every 10 seconds of as many as 39 thermocouples, show a danger signal and act as a valve control or circuit breaker at any one of the 39 thermocouples which have reached the limit of temperature set.



How the WHEELCO SYSTEM Operates

Referring to above sketch: Between the coils "A" (which are attached to and move with temperature limit set pointer "B") a current flows on a given wave length. The heat indicator carries the tiny flag "C" which, when it enters into the coil "A", changes the wave length on the same principle as turning the dials of a radio set. As a result a new wave length is set up, causing the rise in current of a vacuum tube, which in turn starts an electrical relay to function.

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MP1

Please send me data book and literature on instruments checked:

☐ Indicating Control Pyrometers

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Name ....

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Company ....

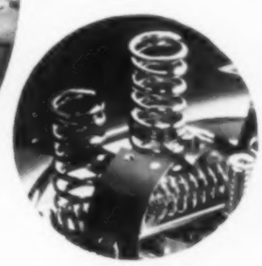
Thermo Control Devices, Inc.

1112 Milwaukee Avenue **Chicago, Illinois**

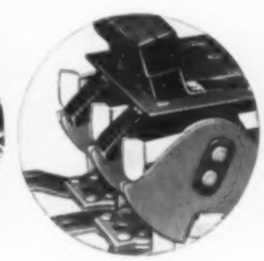
LABORATORY TESTED

To Meet Standard Specifications

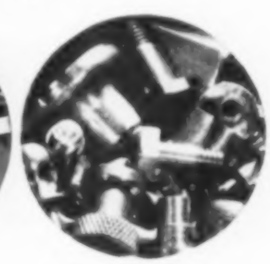
6 Characteristics of Seymour Phosphor Bronze



RESILIENT



"FATIGUE" RESISTANT



FREE CUTTING

BACK of every shipment of Seymour Phosphor Bronze is the thorough work of our well-equipped laboratory. Strict compliance with standard specifications, and with a customer's individual needs, is made a certainty in Seymour Phosphor Bronze by careful, scientific check from melt to final inspection.

In the casting department each heat is numbered and sampled. If satisfactory, the batch proceeds on its way. During its journey frequent tests are made in the laboratory, where hardness, tensile strength, elongation, ductility, grain structure — all important properties — are accurately determined. If at any stage the sample fails to meet the requirements set for the order, the batch is located by its heat number and promptly withdrawn. Any program less rigorous would endanger a standard of uniformity which is a fixed ideal in the Seymour plant.

If you would like to know how Seymour Phosphor Bronze will meet your needs, we will gladly supply samples for test purposes.

DUCTILE

FRICTION RESISTANT

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REMEMBER THE NAME

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Specialists in Phosphor Bronze and Nickel Silver
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such as the rejection of definite crystals of a dispersed phase, demands the presence of an adequate supply of the stranger atoms, it is obvious that progress as a whole will be dictated by the diffusional stage. The actual form of the age hardening law which has been obtained is evidence of this and also that the attainment of maximum hardness constitutes a balance between opposing processes, a view which had previously been supported on the grounds of non-simultaneous attainment of maxima in resistivity and hardness; increase in the latter after the former has begun to fall must mean that cluster formation is still proceeding when definite rejection of alloying atoms in finely dispersed crystals has commenced.

This involves the view that only a limited proportion of the excess solute atoms, usually regarded as available for age hardening, are involved in the clusters at the time of attainment of maximum hardness; in the case of copper-aluminum alloys there is further evidence in that low temperature heat treatment of material previously aged at room temperature at first causes softening (presumably eliminating the previously existing clusters by crystal formation) but later allows hardening to proceed as effectively as in freshly quenched material. It is possible that the behavior of monel metal containing aluminum on reheating at a lower temperature could be explained on the basis of the small proportion of stranger atoms "used" in the first aging; such an explanation would be more satisfactory than Merica's remark in his article in METAL PROGRESS in March (page 48) that this alloy is softened at high aging temperatures "because the hardening constituent goes back into solution."

The relationship developed above is also useful in limiting the experimental work necessary fully to compare the age hardening characteristics of alloys over a range of temperatures. It also furnishes a means of interpolation between results obtained at different temperatures, and estimates may be made on this basis of the stability of the age hardened state. For example, the results of aging duralumin at high temperatures indicate that at room temperature there would be no falling off of hardness within a million years.

E. H. BUCKNALL

SOME NOTES ON BETHLEHEM ALLOY STEELS

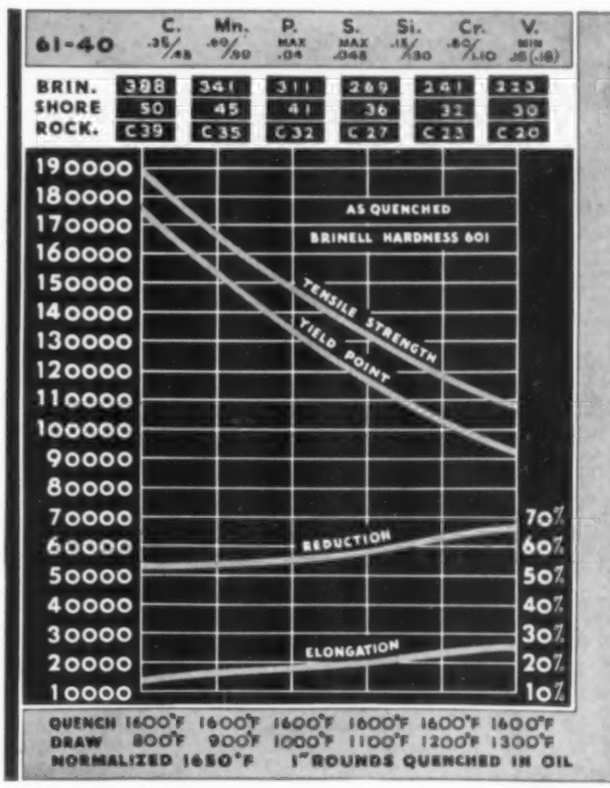
VI - Chrome-Vanadium Steels

THE characteristic property that vanadium imparts when alloyed with steel is finer-grained structure. The benefits of vanadium are not entirely reflected by the percentage that the steel contains. Vanadium is a strong deoxidizer and acts in that capacity when added to the molten metal. The effects of vanadium on the physical properties of a heat-treated steel are to promote ductility and accentuate the benefits of other alloying elements, such as manganese and chromium.

The chrome-vanadium steels, which come under the S. A. E. 61xx Series, carry from 0.80 to 1.10 per cent chromium and a minimum of 0.15 per cent vanadium. These steels are made with a carbon content in standard ranges of from 0.10 to 1.05 per cent. In the lower carbon ranges, up to 0.25 per cent, this type of steel is used for carburized parts, such as pneumatic-tool parts, wrenches, roller-bearing cones, pistons, and other uses subject to wear involving high stresses.

In the 0.35 to 0.45 per cent carbon range, chrome-vanadium steels find application as oil-hardened heavy-duty axles, shafts, driving parts, gears, pinions and similar parts. Because of its resistance to rapid deterioration when exposed to hydrogen gas at high temperatures and high pressures, this grade has also found considerable application in the chemical industry.

Chrome-vanadium steels in the 0.45 to 0.55 carbon range have been used in considerable tonnages



★ *Physical properties of S. A. E. 61-40, a heavy-duty chrome-vanadium steel.* ★

for flat springs. These steels have also been used for coil springs, mostly in the smaller sizes. In the automotive field a flat leaf of chrome-vanadium steel is applied only for special-purpose or heavy-spring steel (10-95) in the spring assembly.

In the higher carbon ranges, chrome-vanadium steel is applied only for special-purpose or heavy-duty work, as in rams, liners, anti-friction bearings, and machine-tool parts.

BETHLEHEM STEEL COMPANY

GENERAL OFFICES: BETHLEHEM, PA.

Alloy Cast Iron

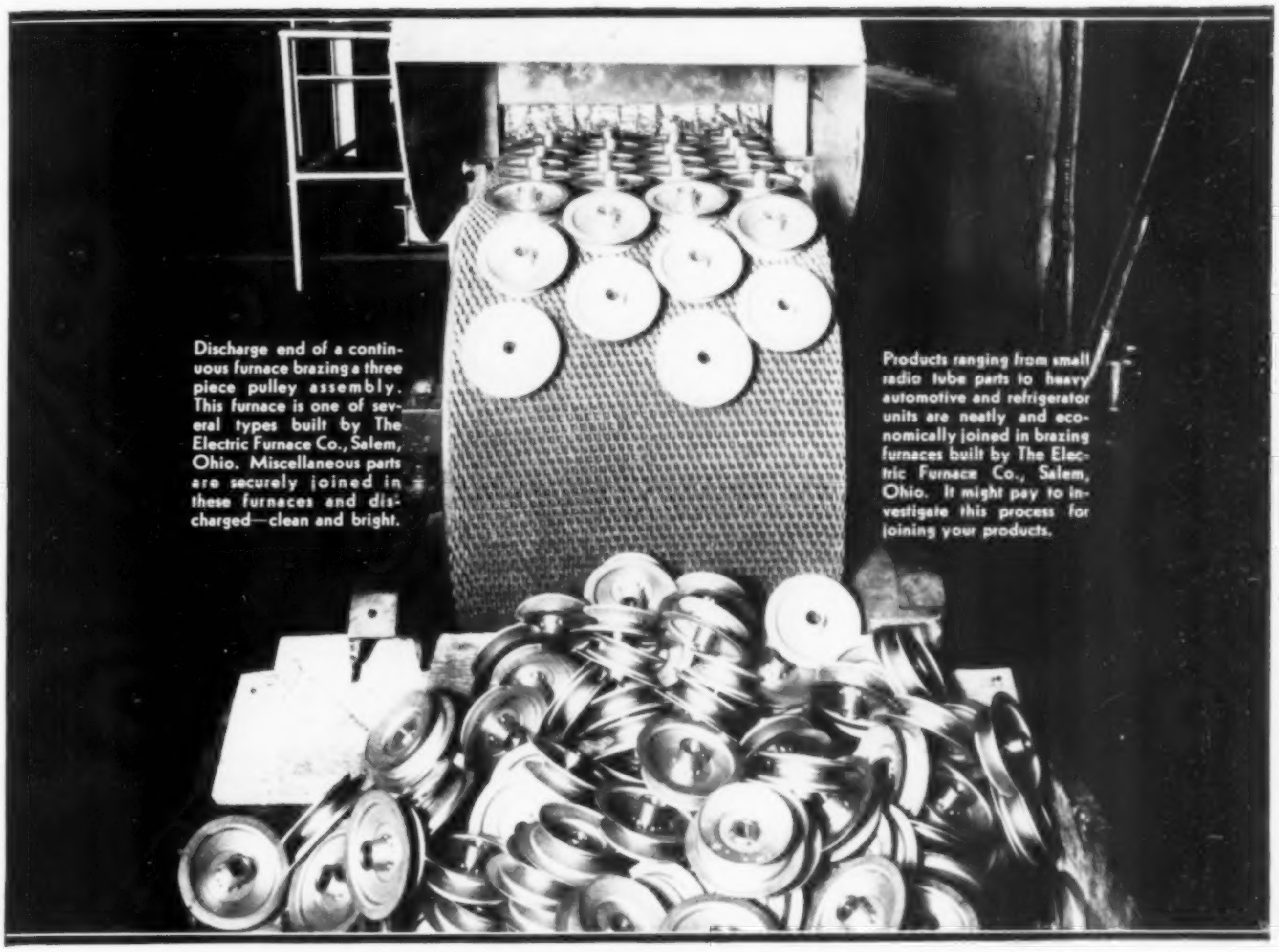
(Continued from page 47)

of the future is likely to be a chilled cast iron, cast white or chilled in the zone where the piston rings travel back and forth. Liners of the 4.5% Ni, 1.3% Cr composition, possessing a hardness over 700 Brinell or 850 Vickers "as cast," have been made. (See the cut on page 47.) Further work will demonstrate whether the resulting high hardnesses obtained can be depended upon to reduce wear to a negligible rate. Castings of this type require the utmost skill on the part of the foundrymen in the production of uncracked castings with smooth, clean surfaces. Wear tests in an Amsler testing machine, running Ni-hard against itself without lubrication indicate a wear rate 8 to 25% that obtained for plain chilled iron run against itself in parallel tests.

Chilled Irons With Machinable Backs

Chemical Analysis				2x6x4-In. Chill Block		
Total Carbon	Silicon	Nickel	Chromium	Depth of Chill	Surface Hardness	Back Hardness
3.62	0.65	—		2.00	464	269
3.63	0.66	0.19		1.80	474	217
3.69	0.70	0.30		1.70	484	212
3.62	0.64	0.61		1.35	491	190
3.62	0.72	1.00		0.45	512	179
3.54	0.74	2.04		Grey	530	192
3.60	0.68	3.52		Grey	573	212
3.54	0.72	5.05		Grey	Grey	232
3.49	0.98	1.53	0.89	1.70	555	286
3.46	1.02	2.89	0.84	0.85	584	316
3.52	1.02	4.34	0.85	0.30	652	387

Most present applications involve wear against abrasives, such as rock, cement, coal, where lubrication is not a factor. Tons of Ni-hard have been made for crusher jaws, rolls, ball and rod mill liners, pump parts, plows, chutes and grizzlies, and for similar castings in the cement, coke, coal, clay, gravel, sand, dredging and farming industries. Sand blast nozzles and equipment for pumping concrete utilize the material. Ni-hard forging dies have also given a good account of themselves.

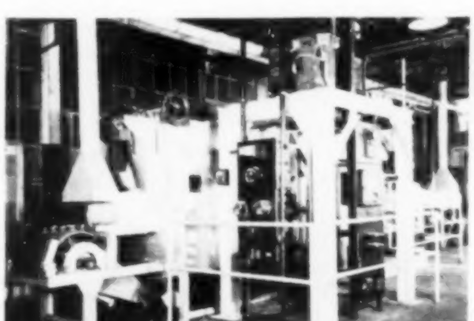


Joining Metal Parts —Neater, Cheaper and Stronger

—by the continuous furnace brazing method

Metal parts in various shapes and sizes—ferrous and non-ferrous—are being joined neatly, securely and economically in continuous brazing equipment similar to that shown above and below. . . . The assemblies are loaded on a traveling belt, carried through this equipment in our special, inexpensive atmosphere and discharged, securely joined—clean and bright. . . . Products difficult or expensive to make in one piece can now be made in several pieces and joined—thus not only reducing the cost but actually improving the quality and appearance. . . . Products requiring several stampings joined or requiring screw machine parts, forgings and stampings to complete the unit, can be neatly and economically joined right in your own shop. . . . Any number of joints in the same product or any number of pieces can be joined at one time. The most intricate parts or assemblies are made to actually "grow together," and joints made which are as strong as the original parts. . . . On some parts it is possible to anneal and braze in one operation. . . . We will be glad to give you additional information, put samples of some of your products through this equipment to show you the results you can expect, and give you an estimate on the cost of the equipment to handle your production, together with operating cost, etc. . . . Investigate the brazing process for *your* products. You can join metal parts, neater, cheaper and stronger by this method.

Our engineers will also be glad to discuss our new developments in bright annealing or scale-free heat treating equipment, or work with you on any of your other furnace or heat treating problems.



Charging end of above furnace showing automatic controls, transformers and generator for producing the inexpensive atmosphere used in this equipment.

THE ELECTRIC FURNACE CO.

Fuel Fired Furnaces

SALEM, OHIO

Electric Furnaces